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ABSTRACT

Materials for teaching a unit on water pollution are provided in this teaching package. These materials include: (1) a student reading booklet; (2) a reference booklet listing a variety of popular chemical, biological, and physical tests which can be performed on a local waterway and providing information about the environmental effects and toxic limits of various potential pollutants; (3) a selection of simple in-class and field experiments printed on loose sheets for ease of reproduction; and (4) a teacher's guide to field testing a local water source. Although there are enough student reading materials, worksheets, and experiments to keep interest high for as long as 5 weeks, a 2 or 3 week unit is recommended. These materials, written at an approximate seventh-grade reading level, are designed especially for, but not limited to, students in grades 7 through 10. (JN)

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WATER, WATER EVERYWHERE, BUT . . . .

By Cliff Jacobson

Notes for the Teacher
Report Writing Directions
Experiments

1983

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Notes for the Teacher

Experiments and Report Writing Directions

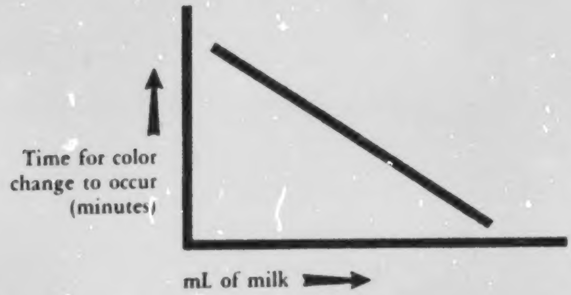
Experiment 1

Teacher Notes

1. You may use fresh or powdered milk. Students will get faster color changes if you warm the milk to room temperature before the experiment.
2. Two liters of milk are enough for five classes of students. If students return unused milk to the jug on your preparation table, there will be plenty left for use by the next class.
3. Many students make mistakes in measuring volumes and will have to repeat the experiment the next day.
4. Most students don't understand the basics of making a graph. It might be wise to spend some time on graphics and graph interpretation.
5. Glassware must be clean and free of soap residue. Soap residue may kill the yeast.
6. All variables in this experiment are relative to one another. Students Won't get good results unless they "handle" each test tube the same way. For example, you can't shake one tube four times and another tube twice!
7. The yeast solution should be well-mixed before it is added to the test tubes. It's important to get approximately the same number of yeast cells in each tube.

Answers to Questions

1. Oxygen
2. Carbon dioxide
3. The oxygen diffuses into the water from the air...or (in a natural setting) is produced by green plants which live in the water.
4. Green plants depend on carbon dioxide that is dissolved in the water. Carbon dioxide is a waste product of animal and bacterial respiration.
5. The color turns to light blue because shaking the tube puts air back into it.
6. Methylene blue is "blue" in the presence of oxygen. Shaking the tube forced air into it which caused the color to change from white to blue.
7. Yeasts require oxygen to live. They produce carbon dioxide as a waste product.
8. The yeasts
9. The milk
10. Test tube 1 had the most sewage; test tube 3 had the least sewage.
11.



12. As the amount of sewage increases, the amount of dissolved oxygen decreases.
13. It would decrease the amount of dissolved oxygen in the water.
14. 16,777,216 or 2^{24} bacteria

Experiment 2

Teacher Notes

1. Students should keep a diligent eye on the test tubes. Color changes often occur in a matter of seconds.
2. Color changes may occur in almost any order...and are correct if students know how to interpret them (see the answer to Question 4 below).

Answers to Questions

1. Cold water. Cold water holds more oxygen than warm water.
2. It would speed up the metabolism of the fish.
3. Faster because of increased metabolic demands. The "biochemical oxygen demand" (see BOD in the **Water Quality Factors** pamphlet) of the fish would "go up".
4. Students should realize all living creatures have minimum, optimum and maximum temperature requirements. Water that is too hot (and boiling is too hot!) will kill some or all of the yeasts, so the color will change slowly or not at all. The concept of minimums, optimums and maximums has far-ranging implications not only for temperature but for other "water quality factors" as well.

Experiment 3

Teacher Notes

1. Select the smallest goldfish you can find for this experiment. Reject any fish that won't fit comfortably into the specimen or baby food jars.
2. A bunsen burner or alcohol lamp is not needed to heat the water in this experiment. Students may simply mix hot and cold tap water until they get the correct (40° Celsius) temperature.
3. This experiment may harm or kill the fish if it continues too long. For this reason it's imperative that you go over the lab directions with the students before the experiment. The entire experiment should take only about 10 minutes *if students know what they're doing!*

Answers to Questions

1. The fish used more oxygen in warm water.
2. The fish probably would die. Respiration rate (and metabolism) would increase.

3a. Average "survival temperature" is 28.7°Celsius.

3b.

Cold Water Fish	Warm Water Fish
Atlantic Salmon	Bluegill
Brook Trout	Carp
Coho Salmon	Channel Catfish
Lake Herring	Largemouth Bass
Rainbow Trout	Northern Pike
Sockeye Salmon	Yellow Perch

4. Any of the warm water fish would be acceptable as long as they aren't all predators.

Experiment 4

Teacher Notes

1. Allow two class periods (80-90 total minutes) to complete the three mini-experiments and answer the questions.
2. Duplicate the *Saturation Monogram* in the **Water Quality Factors** pamphlet and provide a copy for each group of students.
3. Kit directions contain words students won't understand. Be prepared to do a lot of interpretation.
4. Be sure to stress the dangers of the powder pillows before you issue the kits.
5. You don't need an artificial heat source. Warm tap water works fine, although percent saturation values will be higher than for heated water.
6. To make ice water that will keep all day, fill two half-gallon milk cartons and freeze them. Float the cartons in a water bucket the morning of the experiment.

Answers to Questions

1. The aerated sample should contain the most dissolved oxygen simply because it was "aerated." However, either of the other samples may contain more dissolved oxygen. The differences will be reflected in the percent solution values for each water sample.
2. The warm water should contain the least amount of dissolved oxygen. If it doesn't, its saturation value will be higher than the other samples.
3. A ppm (part per million) and mg/L (milligram per liter) are the same. The slight difference that exists between the two does not become significant until extremely high values (5,000 or more) are reached.
4. Yes...but its saturation level would have to be higher.
5. Warm water holds less dissolved oxygen than cold water so there would be less oxygen available for fish and aquatic life.

Experiment 5

Teacher Notes

1. Membrane filtration equipment is easy and fun to use. Students almost always get positive results if enough test are taken.
2. There is little risk of illness even if sterile procedures are eliminated. (However, this is not a license to eliminate them!)
3. School libraries all contain books giving the background on different diseases. Students might be asked to research some of the common water-borne pathogens and their effects on human health.

Experiment 6

Teacher Notes

None...

Answers to Questions

1. Divide the answer from No. 5 (total amount of water which flows downstream each day) by 100.
2. Fish and aquatic life would die. Animals which depend on the waterway for survival also would die.
3. There is no set answer. Student rationale should depend on the size of the stream, the reliability of the water flow...and the number of other communities depending upon it for water.

Water, Water Everywhere, But . . . . .

By Cliff Jacobson

A program for studying environmental science designed especially for — but not limited to — students in grades seven through ten!

To the Teacher

Hardly a day goes by when we don't hear something about water pollution — acid rain, chemical contamination of drinking water supplies (remember Love Canal?), oil-soaked beaches and waste-fouled rivers. Yet, few Americans even know where their drinking water comes from, let alone how it gets polluted!

Junior and senior high school students need to understand the variables affecting the quality of water they depend on for life. But schools don't teach much about "water quality" for a number of very good reasons.

First is the almost total lack of suitable educational materials. What is available for people of junior and senior high school age is either two basic (the Dick and Jane approach) or much too complicated. Texts and experiments, supposedly designed for use in grades seven through ten, invariably are too hard to read, too sophisticated and too boring. And to use them, the teacher must be some sort of water specialist!

That's why we developed ***Water, Water Everywhere, But . . . . .*** It's a *complete teaching package* that clearly and simply unveils the mysteries of water pollution. Everything is written on an approximate seventh-grade level so kids can understand it.* All experiments and procedures have been field-tested by more than 10,000 students in grades seven through ten.

Water, Water Everywhere, But . . . . . was developed by teachers for teachers. It is dedicated to the firm belief that learning about water can be fun!

There are enough student reading materials, work sheets and experiments to keep interest high for as long as five weeks. However, a two- or three-week unit seems about right and will fit in with most any subject — English, math, biology, chemistry, social studies, or . . .

You can't learn about water quality without deeply touching all disciplines.

In this Teaching Package You'll Find:

1. **Student Reading Unit:** basic text for all students. It's complete with diagrams, question sheet and exam. New vocabulary explanations are printed in the margin.
2. A **Water Quality Factors** (Reference Unit) pamphlet: This pamphlet lists a variety of popular chemical, biological and physical tests which can be performed on a local waterway. A wealth of information is given about the environmental effects and toxic limits of each potential pollutant.

   Readings from this section may be assigned at your discretion and are designed specifically to key in with the "on-the-water" experiments suggested in the *Teacher's Guide To Field Testing A Local Waterway*. It is *not* the intent that students should read and digest all the information in the **Water Quality Factors** pamphlet.
3. **Experiments:** A selection of simple in-class and field experiments is included. Experiments are printed on loose sheets for ease of reproduction.
4. ***Teacher's Guide to Field Testing a Local Waterway.*** The "on-the-water" field test is the highlight of this unit. Students love it and really get involved. Minimum amounts of time and equipment are needed for this activity.

How to Use These Materials

1. Reproduce the **Student Reading Unit** or purchase additional copies from the Hach Company. Provide class time for students to read the pamphlet and answer the questions.

   Supplement the **Student Reading Unit** with films and film strips from your school and public library. Your state's department of natural resources probably has a *free* film lending library with many appropriate titles.
2. Begin the "lab block" as soon as possible. *Experiment 3* is recommended especially for students in grades seven through nine. Each experiment requires approximately 30 minutes to complete.
3. If you decide to field test a local waterway, prepare students for the activity well in advance. Specific instructions are given in the *Teacher's Guide*.

Good luck and good teaching . . . . .

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*Computer analysis of the *Readability Index* yields a value of 59 (grades 7-8).

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Name ______________________ Hour __________

Water, Water Everywhere, But . . . . .

QUESTIONS for Student Reading Unit

1. What percent of all water on earth is immediately available for use? __________
2. Pack ice forms in the oceans. Is it composed of salt water or fresh water? __________
3. How many millions are in a billion? __________
4. How much more water do we have under the first half-mile of ground than is stored in all our rivers, lakes and streams? __________
5. How many gallons of water does it take to raise a steer for market? __________
6. Considering agricultural and industrial use, every person in America uses ________ gallons of water per day.
7. Who was Alexander Shrenk? What did he want to do? __________
8. Name two problems that might result if the direction of flow of a major river in Russia were reversed:
   1. __________
   2. __________
9. Why can't we make all the deserts in the world "bloom" by simply irrigating them with fresh water taken from rivers? __________
10. What is ground water? __________
11. What makes water hard? __________
12. Name *two* places in the water cycle where water is cleaned.
    1. __________
    2. __________
13. What is a carcinogen? __________
14. How fast does ground water move? __________
15. What are sanitary landfills? __________
16. Are most sanitary landfills sanitary? Why or why not? __________
17. What is acid rain? __________
18. Normal rain has a pH of about __________
19. A solution with a pH of 2 is ________ times more acid than a solution of pH 6.
20. Name the two acids which form in the atmosphere and cause most of our acid rain.
    1. __________ 2. __________
21. What is a buffer? __________
22. What are two solutions to the acid rain problem?
    1. __________
    2. __________
23. What is ecology? __________
24. Describe three problems which result when large dams are built along rivers.
    1. __________
    2. __________
    3. __________
25. What is an anadramous fish? __________

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Questions (Continued)

26. There's an old saying that if you dump sewage into a river, the river will clean itself in 90 miles. Why is this statement wrong?

27. What does pollution mean?
28. Explain what biodegradable means.
29. Do biodegradable products harm the ecology of a waterway?
Explain: (be specific!)

30. How long does it take for a plastic bag to degrade?
31. What is eutrophication?

32. Why have some states adopted legislation prohibiting building homes too close to a waterway?
33. Give the relationship between the temperature of water and the amount of dissolved oxygen it can hold:
34. What is turbid water?
35. How does turbidity affect a waterway?

36. If you build a shopping center or airport near a waterway, serious flooding may result. Why? (be specific!)

37. What is bio-accumulation?
Name a chemical substance that bio-accumulates:
38. What is an effluent?
39. Most of the man-made radiation is produced by . . .
40. List the three stages of sewage treatment and write a short sentence about each:
1.
2.
3.

Name ______________________ Hour ________

Water, Water Everywhere, But . . . . .

EXAM for Student Reading Unit

MULTIPLE CHOICE

_____ 1. Most of the water in the United States is stored in: a) rivers, b) lakes, c) oceans, d) underground aquifers.

_____ 2. Soviet engineers plan to reverse the flow of at least a dozen rivers in Russia. If this plan is put into practice, it could: a) reduce the amount of salt in the Arctic Ocean, b) cause the polar ice cap to melt, c) increase the number of fish in the south of Russia, d) be so expensive it couldn't possibly succeed.

_____ 3. Disturbing new evidence suggests we may be "mining" water from our deep underground aquifers in the Southwest. This means: a) there are many valuable minerals in this area, b) special "mining machinery" is required to get the water out, c) we're using up the water faster than nature can replace it, d) water in this area is not fit to drink.

_____ 4. Too many minerals in water may make it: a) hard, b) soft, c) mushy, d) poisonous.

5. Salty ocean water evaporates as: a) salt water, b) fresh water, c) water that is half fresh, half salty, d) it doesn't evaporate!

_____ 6. A substance which may cause cancer is called: a) a cancer-causing agent, b) salinization, c) desalinization, d) a carcinogen.

_____ 7. Ground water that becomes contaminated by chemicals: a) may be cleaned by filtering it through a screen attached to your water faucet, b) may take many years to clean by natural processes, c) will not flow to the surface of the earth and evaporate, d) may be cleaned by adding buffers which lower its pH.

_____ 8. A solution that has a pH of 10 is *how many times* more alkaline than a solution of pH 8? a) 10, b) 100, c) 1,000, d) 10,000

_____ 9. There are two places in the water cycle where polluted water may be cleaned. These are: a) evaporation and precipitation, b) precipitation and filtration through the ground, c) evaporation and filtration through the ground, d) evaporation and eutrophication.

_____ 10. Acid rain has a pH: a) below 5.6, b) of exactly 7.0, c) above 7.0, d) below 2.0.

_____ 11. Name the two gases most responsible for producing acid rain: a) sulfur and nitrogen oxides, b) nitrogen and potassium oxides, c) nitrogen and phosphorus oxides, d) oxygen and carbon dioxide.

_____ 12. The main cause of acid rain is: a) nuclear power plants, b) private homes which burn natural gas, c) city sewage treatment plants, d) automobiles and coal-fired power plants.

_____ 13. Substances which absorb and neutralize acids or bases are called: a) neutralizers, b) acid-base equalizers, c) buffers, d) gnomes.

_____ 14. Dams: a) may disturb the breeding cycles of simple organisms, b) prevent fish from traveling up and down river, c) may change the currents, water depth and amount of oxygen in the water, d) all of the above.

_____ 15. Salmon are an example of: a) gregarious isotherms, b) anadramous fish, c) monagamous fish, d) rough fish.

_____ 16. If you dump sewage into a river, the river may not "clean itself in 90 miles" because: a) too many people (and towns) put sewage into rivers, b) sewage treatment plants are located more than 90 miles apart, c) rivers can't clean themselves — only man can clean up polluted waters! d) there aren't enough bacteria to do the job in that short of a distance.

(Continued on back)

_____17. In which (if any) of these situations are you polluting? a) You wash a pair of socks in a popular lake near your home, b) You wash a pair of socks in a very remote lake deep in the Amazon jungle, c) Neither situation, d) Both situations.

_____18. Products which can be broken down into harmless chemicals by living organisms are: a) biological, b) biodegradable, c) biochemical, d) sediments.

_____19. The aging process whereby lakes absorb too many nutrients and die is called: a) decomposition, b) concentration, c) nitrification, d) eutrophication.

_____20. Warm water can: a) hold more dissolved oxygen than cold water, b) hold less dissolved oxygen than cold water, c) hold the same amount of dissolved oxygen as cold water.

_____21. The major causes of thermal pollution are: a) cars and trucks, b) furnaces in homes, c) sewage treatment plants, d) nuclear and coal-fired power plants.

_____22. Silt may get into waterways: a) when soils erode after a logging operation, b) when soils erode after a strip-mining operation, c) if the watershed is rocky with little vegetation, d) all of the above.

_____23. If you build a shopping center or airport near a lake or river: a) short-term eutrophication may result, b) the area around the waterway may flood after a heavy rain, c) the waterway will be polluted by raw sewage, d) there will be no ecological effects on the waterway.

_____24. Mercury, lead, PCBs, and DDT are all examples of chemical compounds which: a) cause brain damage, b) are carcinogenic, c) cannot be removed from water, d) bio-accumulate in organisms.

_____25. Man may cause the death of a body of water from "eutrophication" if: a) he dumps biodegradable wastes and/or fertilizers into the water, b) he dumps poisonous wastes into the water, c) he dumps sediments into the water, d) he allows radioactive wastes to enter the water.

_____26. The chemical used to kill bacteria in sewage treatment plants is: a) alcohol, b) PCBs, c) chlorine, d) phosphate.

_____27. Which stage of sewage treatment is biological in nature? a) primary, b) secondary, c) tertiary or advanced.

_____28. Water hyacinths are: a) flowering water plants, b) pests in southern states, c) a help to San Diego in cleaning its sewage d) all of the above

_____29. Which stage of sewage treatment can produce water clean enough to drink? a) primary, b) secondary, c) tertiary or advanced.

_____30. Solving water pollution problems is: a) unimportant, b) impossible, c) easy, d) everybody's concern!

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Water, Water Everywhere, But . . . . .

TEACHER'S KEYS

Answers to Student Reading Unit *Questions*

1. 0.8
2. Fresh
3. 1,000
4. 20 times more
5. 7,000
6. 1,000
7. A Soviet surveyor. He wanted to divert the Pechora River into the Volga.
8. 1. Towns and seaports would be destroyed; fish would die.
   2. The Arctic Ocean might get too salty; the polar ice cap might melt.
9. There's not enough fresh water. The rivers we'd use for irrigation would run dry.
10. Water that flows beneath the ground
11. Minerals
12. 1. When it evaporates from waterways
    2. When it is filtered through the ground
13. A substance able to cause cancer
14. Very slowly — less than 100 feet per year
15. Dumps that don't pollute the environment
16. No! Many of them have not been located in an area where they will not pollute the air and water. (Teachers note: *Sanitary landfills* are ordinary "dumps" and should not be confused with much rarer *hazardous wastes dumps* which have special linings to prevent the seepage of harmful chemicals.)
17. Rain which has a pH of less than 5.6
18. 5.6
19. 10,000
20. 1. Nitric 2. Sulfuric
21. A substance that can neutralize an acid or base without appreciably changing its own character
22. 1. Burn fewer fossil fuels
    2. Install pollution control devices in factories and cars
23. Study of the relationship between organisms and their environment
24. 1. Fish can't move freely up and down river (disrupts their breeding).
    2. Impounded waters may get too warm and fish may die.
    3. As water levels change, currents, water depth and amount of dissolved oxygen also may change.
25. Fish that live in salt water but lay their eggs in fresh water
26. River towns are too close together today; the sewage load on the river is too great.
27. "Too much"
28. "Can be broken down by living things"
29. Yes! They are food for bacteria and algae. These microbes eat the wastes and reproduce. Oxygen levels in the water drop and fish die.
30. About 2,000 years
31. "Enrichment with nutrients" (Lakes age and fill with sediments. Eventually, they cease to exist.)
32. To eliminate pollution from faulty sewage systems
33. Warm water can hold less oxygen than cold water.
34. Cloudy water — produced when silt washes in
35. Reduces photosynthesis, buries fish and shellfish spawning areas
36. The large concrete or blacktop surface changes the drainage pattern of the area.
37. The process by which certain substances accumulate in an organism or in your body
38. A liquid that flows out of some place (sometimes used to refer to liquid wastes)

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39. Nuclear bomb fallout, nuclear weapons testing, nuclear energy plant accidents, uranium mining operations, research laboratories and hospitals.
40. 1. Primary — removes scum and stuff that settles (sludge)
    2. Secondary — a biological process in which bacteria eat sewage
    3. Tertiary or advanced — a chemical process which removes harmful chemicals from the water

Answers to Student Reading Unit *Exam*

1. D
2. B
3. C
4. A
5. B
6. D
7. B
8. B
9. C
10. A

11. A
12. D
13. C
14. D
15. B
16. A
17. A
18. B
19. D
20. B

21. D
22. D
23. B
24. D
25. A
26. C
27. B
28. D
29. C
30. D

Teacher's Guide to Field Testing a Local Water Source

By Cliff Jacobson

General Overview

Students are bused to a small creek, stream or river. Here, they work in small groups to test the water for the presence of selected pollutants listed in the **Water Quality Factors** pamphlet.

Each group of students runs a battery of three to four different tests. For example: One group may test for *dissolved oxygen, five-day BOD, temperature*, and *phosphates*. Another group may determine *nitrates, chlorides, volume and velocity* and *turbidity*. Tests are repeated over and over at places along the stream until the quantity of time allotted for the field trip has expired.

The repetitive tests:

1. Teach students that because rivers (streams or creeks) move constantly, contaminant levels may change from day to day or moment to moment. And . . . that scientific experimentation is not a "one shot affair."
2. Illustrate that contaminant levels vary from place to place along a moving waterway. Variables like velocity, volume and number of eddies, can affect test results.
3. Keep students occupied "until the bus returns." Idle hands make for big problems on field trips!

When students return from the river they work together to prepare a "scientific report" which follows the guidelines presented in *Directions for Writing the Lab Report*.

Where to Do the Activity

A *shallow* (less than two feet deep) creek or stream is better than a lake for these reasons:

1. You don't need a boat or dock to take samples. All that's necessary is one pair of rubber boots per group (hip boots are ideal). Warm weather needs would include sneakers and rolled-up jeans for everyone.
2. Students can't drown in a shallow stream. They *can* in a lake!
3. Test results often vary more in a stream than a lake.
4. You can determine the velocity, volume and profile of a stream — a fun activity requiring no equipment other than a measuring tape or rope, a meter stick and two wooden stakes. *(See Experiment 6.)*
5. Students maintain a keener interest if they can "walk in the water" to obtain water samples. And they have a lot more fun, too!
6. You can provide each group with a "sample map." (See the Sample Map" with numbered stations at the end of this "Guide.") The idea is to perform a battery of tests at each numbered station. This is more interesting than simply sitting along a lake shore dipping water from the edge. If you include enough stations so that students can't possibly get to them all in the given time, you'll have few problems with "idle hands and idle minds."
7. There's a shallow creek or stream within a 15-minute bus ride of almost every school.

Group Size

Groups of three to four students are ideal. This leaves two or three people to operate the test equipment and record data and one person to collect water samples.

Amount of Time Required to Do the Activity

One hour "on the water" is all the time you need or want. A 100-minute time block will give you plenty of time for the bus ride and to clean equipment for use by the next class.

You may be most successful in "selling" the field trip experience to your administration if you point out these facts:

1. It is the highlight of your water unit . . . and it is *real* experimentation!
2. It is a "one time thing," not a weekly event.
3. It has a proven safety record! At the Hastings, Minnesota Junior High School, we've *never* had a cut, bruise or any type of accident in the nine years we've been doing the activity.

Prerequisites to the Field Trip

1. All students should read the **Student Reading Unit** and take the test.
2. Students should at least complete *Experiment 4*.
4. Students should read about the tests they will perform on the river in the **Water Quality Factors** pamphlet.

Preparations

Generally, you should allot *three days* of preparation time before the field trip and *one day* of "write-up" time after the field trip. Then, sequence the time as follows:

DAY 1

1. Give a general overview of the activity and tell what is expected.
2. Divide the class into groups and assign test responsibilities based on the equipment you have. It makes no difference if several groups perform the same tests. This is first and foremost a learning experience. Whatever you find out about the quality of water in the river is secondary.
3. List on the board individual equipment (such as clothing) students will need for the field trip. (See *Equipment* at the end of this "Guide.")
4. Any remaining time should be used for preparing the *Background Information* section of the student reports. See *Directions for Writing the Lab Report*.

If you assign four different tests to each group of four students, each student can prepare the *Background Information* on one of these four tests. All the necessary research information is given in the **Water Quality Factors** pamphlet.

The *Background Information* section of the reports should be completed *before* students go to the river. This will give them a better understanding of what they're doing and how each pollutant or variable affects the quality of water.

DAY 2

Work with each group individually and show each group exactly what is expected — how to use the test kits, how to record data and basic precautions.

One good idea is to make up a "chemical brew" for students to test. Your chemistry teacher can supply small amounts of chemicals containing phosphates, nitrates, chlorides and/or acids. If you're really industrious, *you* can determine the amount of each pollutant in the brew with your Hach Test Kits. Students can compare their results to yours. However, this isn't essential. As long as kids get positive (and colorful!) results, they'll work diligently.

You'll need about two class periods to get around to all the groups. In the meantime, students not being counseled may work on their *Background Information* write-ups.

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DAY 3

1. Students practice using the water test equipment as you work with individual groups.
2. Check student *Background Information* write-ups today. Grading can come later. Right now, it's important only to see that students have completed the necessary prerequisites to go on the field trip.
3. Remind students of the individual clothing and equipment they must furnish in order to "go to the river."

EQUIPMENT

Each student should furnish the following equipment for the field trip:

Individual Equipment

- A complete change of clothes in a plastic bag. Students *will* get wet — accidentally and on purpose. (Author's note: I sternly warn kids about the consequences of goofing around, but I'm never 100 percent convincing.) And, if the weather turns cold, extra clothing is essential.
- A sitting pad of some sort. A plastic trash bag stuffed with folded newspaper works fine. It's no fun sitting in the mud or on cold rocks while you perform water tests.
- A rain coat or large "leaf and lawn" size plastic bag. If it rains, you're stuck until the bus comes. You can fashion an emergency raincoat from a big plastic trash bag.
- Optional: Encourage kids to bring snacks, soft drinks, or a thermos bottle of hot chocolate. This is a good time to teach the environmental ethic: "leave only footprints." This is an environmental education activity; it's imperative that the area be left cleaner than you found it!
- Outer clothing (coats, hats, mittens) if necessary

Group Equipment

- Encourage each group to bring a pair of hip boots or waders.
- One "clip board" per group facilitates note-taking in the field. (Encourage groups to keep *two* sets of test results so they'll have something to fall back on in the event one set of results is lost.)
- A plastic bag (quart size is fine) for trash

Equipment Furnished by the Teacher

- A first-aid kit. (You may obtain one from the school nurse.)
- A cardboard box filled with test kit accessories. A list might include extra glassware and chemicals for the test kits, a few thermometers, a plastic hand-pump and forceps for the membrane filter apparatus, a few rolls of masking tape and some marking pens for labeling samples, some river maps and blank "results tables." (See the form on the next page of this guide.)

Students will break some glassware on the river, so be prepared! *Caution:* Provide large plastic cups, ice-cream buckets and cut-off bleach or milk jugs for sampling. Don't allow students to use the kit glassware for sampling; it's dangerous and a sure recipe for lost or broken items.

Essential Water Test Equipment

See *Teacher's Guide to Ordering* at the back of the **Water Quality Factors** pamphlet for a listing of recommended kits.

The number and kinds of tests that can be performed are limited only by the kind and amount of water test equipment your school owns. The more equipment, the more diversified your tests can be . . . and the more interesting your findings. However, students can have a meaningful experience even if you have only enough equipment to test for a few variables.

Dissolved oxygen test kits are your most essential purchase. With these you can do the *five-day BOD* and "on the water" *dissolved oxygen* experiments. Add a thermometer, and you can also determine *percent saturation* of oxygen and *temperature* — four different tests for the price of one kit and a thermometer.*

The first year Hastings Junior High tested a local stream, seven classes of students (about 200 kids) shared the following equipment:

— Three Model AL-36B Water Ecology Test Kits

— Two Model OX-2P Dissolved Oxygen Test Kits

— One Model PO-19 Orthophosphate Test Kit

— One membrane filter set-up (for turbidity and coliform bacteria experiments)

— Several thermometers

— Two 50-foot nylon ropes — calibrated each foot with tabs of plastic tape

Enough additional glassware was purchased from Hach Company to assemble three more *dissolved oxygen* "kits." We kept these kits in two-pound cans obtained from the cafeteria. Kit directions were duplicated and taped to the face of the cans.

Hastings Junior High's battery of water test equipment has grown considerably since those early days nine years ago. Nevertheless, the original inventory was quite adequate for a "good experience."

School officials usually are much more understanding about purchasing chemicals and glassware than "new test kits." With ingenuity, you can purchase enough additional glassware and chemicals to assemble a number of duplicate test kits at low cost.

Equipment Maintenance

Each group of students should elect a "captain" to be responsible for seeing that equipment is sparkling clean and in good order after each use. The "captain" receives extra-credit points for his or her efforts. *You* must check each kit carefully after it is used by students. Failure to do this invariably will result in loss, breakage or theft of everything!

Thermometers: Thermometers will break instantly if you don't take some precautions. A simple method is to tape them to meter sticks (mercury bulb well up on the stick).

Precautions

The Hach kits come equipped with convenient premeasured chemicals packed in lengths of sealed plastic tubing. These "powder pillows" are attractive toys to some students. We had one instance where a student stole some powder pillows and attempted to sell them as drugs! It's imperative that you tell students in no uncertain terms that powder pillows contain very poisonous chemicals — chemicals that can kill if taken internally! Seek the administration's help to prevent problems. At Hastings Junior High, the policy is: *Any student caught outside the room with a powder pillow in his or her possession is reported to juvenile authorities and is excluded from all future laboratory experiments and field trips.* (Author's note: In nine years, we have had to enforce this policy only twice!)

After the Field Trip

Allow one day after the field trip to share results and complete the project.

Forms

You'll find the form and sample map which follow are very useful.

---

*Be sure to get laboratory thermometers which are graduated in degrees Celsius.

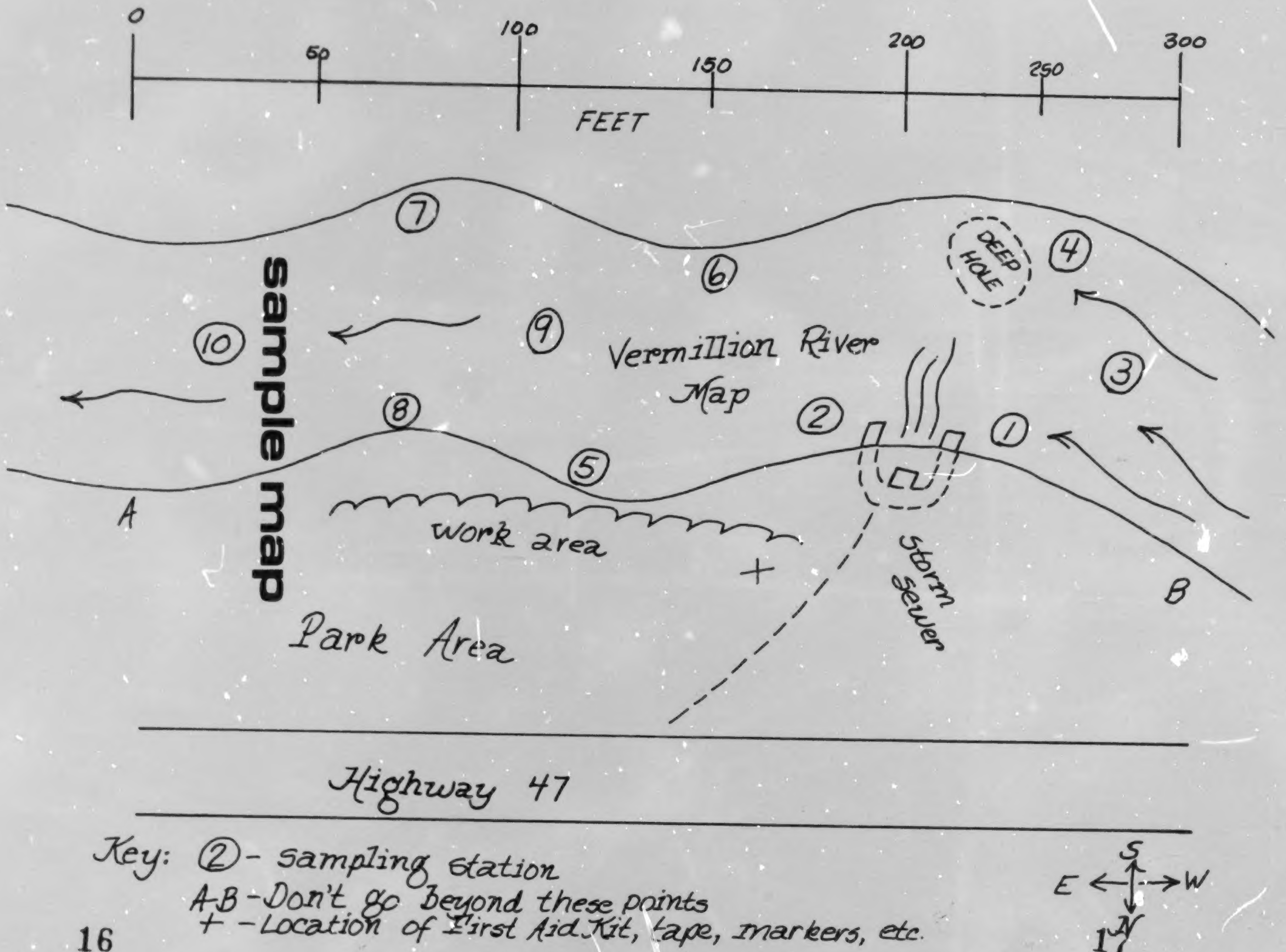
Date of testing ____________ Year ________ Name ________________ Hour ________

Table of Results

Station Number	Time (to nearest minute) of Testing	Name of Tests Performed*									
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

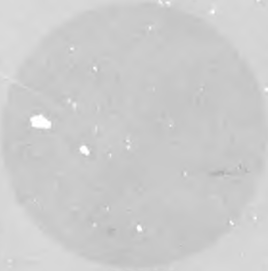
*Don't forget to include the *units* (example: mg/L, gpg or ft^2)

(Continued on back)

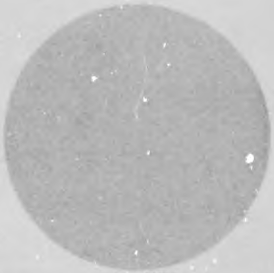

0
50
100
150
200
250
300
FEET
sample map
Vermillion River Map
⑦
⑥
DEEP HOLE
④
⑨
⑩
③
②
①
⑧
⑤
A
B
work area
+
Storm Sewer
Park Area
Highway 47
Key: ② - sampling station
A-B - Don't go beyond these points
+ - Location of First Aid Kit, tape, markers, etc.
S
E
W
N

Turbidity Color Chart

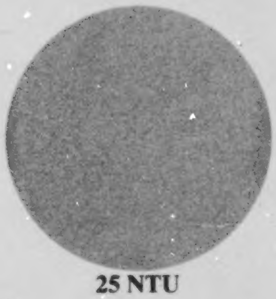
For use with Turbidity Experiment on pages 28 and 29 of the **Water Quality Factors** *pamphlet*



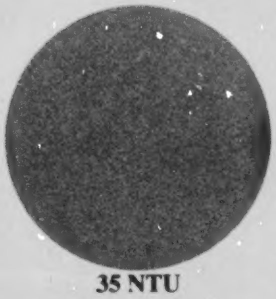
8 NTU



16 NTU



25 NTU



35 NTU

45 NTU

Read This *Before* You Test Turbidity

1. The color of *your* membrane filter may vary from the colors on the chart. That's because different materials caused the turbidity or cloudiness in *your* sample. For instance, if your stream contains a large number of blue-green algae, your filter will be greener than those shown on the chart.

Don't worry about the color difference. Just match the *depth* of color of your filter to the *depth* of color on the chart. If you do this, you will obtain a fairly reliable "guesstimate" of turbidity.

2. One-hundred mL samples with turbidities of more than 40 or 50 NTU (Nephelometric Turbidity Units) will be *very* difficult to filter — even with a hand pump. So, if the water looks cloudy, use a *smaller* sample. Then, choose the formula from the table below that matches your sample size and calculate the turbidity for your sample.

Sample Size (in mL)	×	Chart Reading (in NTU)	×	Sample Size Factor	=	Sample Turbidity (in NTU)
75	×	________	×	1.33	=	________
50	×	________	×	2	=	________
25	×	________	×	4	=	________
10	×	________	×	10	=	________

How to Calculate

Suppose your sample looks cloudy and you decide to filter only 25 mL through the membrane filter apparatus. When you compare your filter to the chart, you read the turbidity as 16 NTU. Then you check with the table and find you should multiply your reading by 4 to obtain the sample turbidity. You report 64 NTU (4 × 16 NTU = 64 NTU) as the turbidity of your sample.

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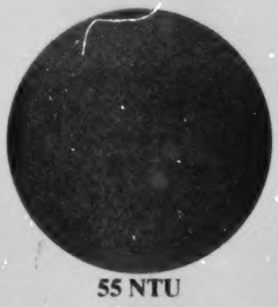
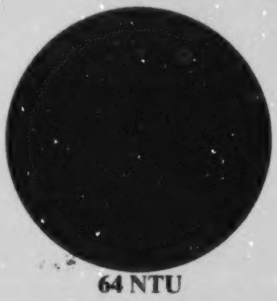
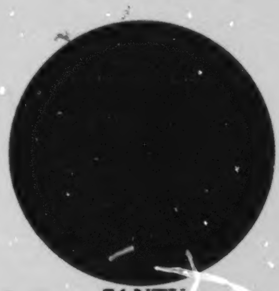


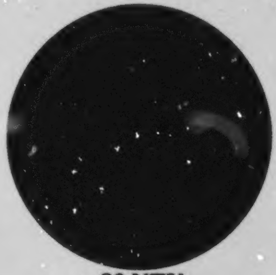
55 NTU



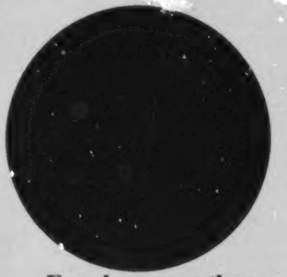
64 NTU



74 NTU



83 NTU



Equal or more than
93 NTU

Test Kit and Reagent Price List for Educators

Effective 4-1-83

Please call 1-800-525-5940 for information about quantity discounts. (Colorado residents: call 669-3050 collect)

Cat. No.	Description	Price
151-11	Nessler Reagent, 473 mL (1 pt)	$14.00
151-37	Nessler Reagent, 118 mL (4 oz)	8.25
211-26	Phenol Red, 58 mL (2 oz)	3.95
211-36	Phenol Red, 15 mL (½ oz)	3.25
211-37	Phenol Red, 118 mL (4 oz)	6.25
213-01	UniVer* 3 Powder, 454 g (1 lb)	19.95
213-14	UniVer 3 Powder, 113 g (4 oz)	9.95
213-20	UniVer 3 Powder, 28 g (1 oz)	5.25
216-16	pH Indicator, 946 mL (1 qt)	24.50
216-37	pH Indicator, 118 mL (4 oz)	8.25
349-16	Starch Indicator, 946 mL (1 qt)	7.25
349-37	Starch Indicator, 118 mL (4 oz)	4.75
397-11	Chloride Test Solution, 473 mL (1 pt)	23.25
397-37	Chloride Test Solution, 118 mL (4 oz)	10.50
413-11	Sulfuric Acid Solution, 473 mL (1 pt)	6.50
413-37	Sulfuric Acid Solution, 118 mL (4 oz)	4.95
424-11	Hardness No. 1 Solution, 473 mL (1 pt)	7.50
424-37	Hardness No. 1 Solution, 118 mL (4 oz)	6.00
425-11	Hardness No. 2 Solution, 473 mL (1 pt)	9.95
425-37	Hardness No. 2 Solution, 118 mL (4 oz)	6.50
426-11	Hardness No. 3 Solution, 473 mL (1 pt)	6.50
426-37	Hardness No. 3 Solution, 118 mL (4 oz)	5.25
438-00	Plastic Measuring Tube, 5.83 mL mark	0.90
505-43	Erlenmeyer Flask, 125 mL	1.50
511-00	Measuring Spoon, 0.1 g	0.55
546-46	Filtering Flask, 250 mL	6.15
671-11	Sodium Hydroxide Solution, 473 mL (1 pt)	7.75
671-37	Sodium Hydroxide Solution, 118 mL (4 oz)	5.75
936-00	Clippers, for opening powder pillows	0.70
942-99	Phenolphthalein Powder Pillows, 100	7.00
943-99	Bromcresol Green-Methyl Red Powder Pillows, 100	6.75
962-99	UniVer 3 Powder Pillows for Hardness, 100	6.95
981-99	Dissolved Oxygen No. 1 Pillows, 100	6.75
982-99	Dissolved Oxygen No. 2 Pillows, 100	6.75
987-99	Dissolved Oxygen No. 3 Pillows, 100	10.50
1043-99	Chloride Powder Pillows, 100	6.95
1055-99	Sulfamic Acid Pillows, 100	6.50
1059-11	Detergents Test Solution, 473 mL (1 pt)	21.25
1059-37	Detergents Test Solution, 118 mL (4 oz)	8.75
1077-99	Potassium Iodide Pillows, 100	9.50
1079-11	PAO Solution, 473 mL (1 pt)	6.95
1079-37	PAO Solution, 118 mL (4 oz)	5.25
1432-03	Detergents Test Kit, Model DE-2	136.50
1433-00	Alkalinity Test Kit, Model AL-AP	18.00
1436-01	Carbon Dioxide Test Kit, Model CA23	18.00
1440-00	Chloride Test Kit, Model 7P	22.50
1452-01	Hardness Test Kit, Model HA-71A	24.00
1453-00	Hardness Test Kit, Model 5B	7.75
1454-00	Hardness Test Kit, Model 5-EP	14.50
1469-00	Dissolved Oxygen Test Kit, Model OX-2P	42.50
1470-11	Wide Range pH Test Kit, Model 17N	56.75
1730-00	Color Viewing Tube, marked for 5 mL	1.15
1731-00	Stopper for Cat. No. 1730	0.60
1736-00	Color Viewing Tube, marked for 5 and 20 mL	1.60
1802-02	Water Ecology Kit, Model AL-36B	110.00
1834-00	Hexavalent Chromium Kit, Model CH-8	41.00
1847-11	PAO Solution, 473 mL (1 pt) for chromate test	21.75
1847-37	PAO Solution, 118 mL (4 oz) for chromate test	7.25
1897-11	Phenolphthalein Solution, 473 mL (1 pt)	8.50
1897-36	Phenolphthalein Solution, 15 mL (½ oz)	3.25
1909-01	Extra Stopper for Bottle (No. 1909-02)	2.85
1909-02	Glass Stoppered Bottle with 60-mL Mark	5.25
1926-00	Viewing Tube, short for pH	1.25
2118-02	Rubber Stopper, pkg of 12	1.25
2209-28	Phosphate Test Reagent, Bulkpac of 1000	99.00
2209-99	Phosphate Test Reagent, 100 pillows	11.95
2227-02	Hexavalent Chromium Test Kit, Model CH-14	27.50
2231-03	Total Chlorine Test Kit, Model CN-66T	31.00
2241-00	Ammonia Test Kit, Model NI-8	33.50
2248-00	Phosphate Test Kit, Model PO-19	45.95
2327-06	Marked Mixing Bottle, pkg of 6	7.10
12519-00	pH Test Cube Kit	10.95
12522-00	Phosphate Test Cube Kit	10.95
12527-00	Chromium Test Cube Kit	10.95
12710-28	Chromium Test Pillows, Bulkpac of 1000	99.00
12710-99	Chromium Test Pillows, pkg of 100	11.95
13529-00	Filter Holder for Membrane Filtration	77.30
13530-00	Filters w/o Grid, pkg of 100	37.90
14035-99	Nitrate Test Pillows, pkg of 100	13.00
14037-00	Nitrate Test Cube Kit	10.95
14076-28	Total Chlorine Test Pillows, Bulkpac of 1000	74.00
14076-99	Total Chlorine Test Pillows, pkg of 100	8.25
14078-99	Nitrite Test Pillows, pkg of 100	9.95
14081-00	Nitrate-Nitrite Test Kit, Model NI-12	64.50
14120-99	Nitrate Test Pillows, pkg of 100	15.50
14151-00	Nitrate Test Kit, Model NI-14	41.00
14197-00	Glass Dropper, marked for 0.5 and 1.0 mL	1.05
14283-00	Hand-operated Vacuum Pump	28.55
14458-11	Chloroform, 473 mL (1 pt)	16.25
14458-17	Chloroform, 3.76 L (1 gal)	81.00
14480-01	Stopper, hollow, pkg of 6	1.60
14537-00	Forceps	2.65
14852-00	Sterile Petri Dishes, plastic, pkg of 500	71.50
14918-00	Absorbent Pads with Dispenser, pkg of 1000	65.95
19073-00	Cap for Color Cube	0.60
20596-00	Nitrite Test Cube Kit	10.95
20604-00	Total Chlorine Test Cube Kit	10.95
20877-60	Alcohol Burner, 60-mL volume	2.45
20972-00	Safety Goggles	9.50
21233-01	Pipet, sterile, plastic, 1 mL, pkg of 200	36.10
21269-00	Sterile Filters with Pads, pkg of 100	38.00
21273-00	M-Endo Broth Ampules, pkg of 20	14.00
21627-00	Bunsen Burner, works on propane	10.50
21777-14	Eosin Methylene Blue Agar, 113 g (¼ lb)	19.50
21974-00	*Water, Water . . .*, Reference Unit	3.00
21975-00	*Water, Water . . .*, Student Reading	3.00
21976-00	*Water, Water . . .*, Teacher's Packet	4.00

*UniVer is a registered trademark of Hach Company.

Hach Company, Box 389, Loveland, CO 80539

Prices are FOB Ames, Iowa and are subject to change without notice.

Name ______________________________ Hour __________

Experiment 1: Effects of Biodegradable Waste on Dissolved Oxygen

GENERAL: In the **Student Reading Unit** you learned when microorganisms (bacteria and fungi) eat biodegradable wastes, they use large amounts of oxygen. Thus, *a lot of biodegradable waste means very little dissolved oxygen for fish and aquatic life.*

In this experiment, you will challenge the above relationship. Yeast will represent the microorganisms, milk is the biodegradable waste, and methylene blue (a dye) will indicate when oxygen is used up. The methylene blue will change from "blue" to "white" when no more oxygen is present in the test tubes. (The color change is actually from blue to colorless. The white color you'll observe in the test tubes is due to the color of the milk.)

MATERIALS

2 small beakers or baby food jars
2 mL (about half a teaspoon) of dry yeast
(one tsp = 4.9 mL)
or a graduated medicine cup
One 10-mL graduate cylinder,

3 test tubes in a rack
Stirring stick
One 5-mL pipet or an eye dropper
Methylene blue solution

DIRECTIONS

1. Fill a baby food jar about half full of milk and take it to your lab table.
2. Clean three test tubes, place them in a rack and put masking tape numbers (1, 2, 3) on them.
3. Use your pipet *or* eye dropper (there are around 15 drops to one mL) to add the amount of materials to each test tube shown below:

Test Tube	Milk (mL)	or Drops	Water (mL)	or Drops
1	2.5	37	0	0
2	1.0	15	1.5	22
3	0.2	3	2.3	35

Before you go on to the next step, check the height of the liquid in the three tubes. It should be the same. You should have *exactly* 2.5 mL of solution in each tube!

4. Add three drops of *methylene blue* to each test tube. The methylene blue is an "indicator" solution. It will change from blue to white when the oxygen in the test tube is used up.
5. Mix each tube by putting your thumb over the top and inverting it (turning it upside down) smartly *four* times.
6. Prepare a sample of yeast by adding 2 mL (or about one-half a teaspoon) of dry yeast to 20 mL of water *in a beaker or baby food jar.* Mix the yeast and water thoroughly with your mixing stick.
7. You are now ready to mix the yeast and milk solutions. Follow these directions carefully:
   a. Observe the clock for exact timing. Proceed to the *next step (b)* when the second hand passes the "12." Record the *exact* time of mixing — on the minute — in the *Table next to Test Tube 1.*
   b. Mix the yeast solution vigorously with the tip of your pipet or eye dropper. Then carefully put exactly 2.0 mL (30 drops) of yeast solution into Test Tube 1. Mix the test tube by putting your thumb over the top and inverting it smartly *four* times.
   c. Now repeat the procedure with Test Tubes 2 and 3. Be sure you record the *exact* time you added the yeast to each tube!

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(Continued on back)

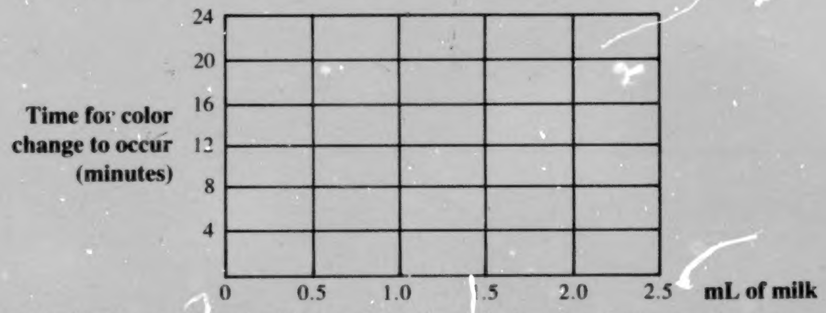
8. Relax and wait until the color of each tube changes from blue to white. (Note: the *surface* of each tube always will remain blue. Can you guess why?)
9. When the color change is complete, figure the *total* time by subtracting the *time of mixing* from the *time the tube changed color*. Report this time to the nearest minute. It may take several minutes for the tubes to change color, so be patient.
10. Check your results with your teacher. Then answer the following questions:

Test Tube	Time of Mixing (on the minute) (A)	Time When Tube Changes Color (B)	Total Time for the color change to occur (B minus A)
1			
2			
3			

Note: It usually takes about 15 minutes for a color change to occur. If you haven't added the yeast by 15 minutes before the end of your class period — forget it! You'll have to repeat the lab test in another class period.

QUESTIONS

1. Name the gas "inhaled" (taken in) by microorganisms.
2. Name the gas "exhaled" by microorganisms.
3. Where do microorganisms living in water get the oxygen they need to live?
4. Where do green plants living in water get the carbon dioxide they need to live?
5. Shake one of your test tubes which has "turned white." What happens to the color? Why does the color change?
6. Air is added naturally to rivers when the water goes through rapids and over falls. How does "shaking the test tube" prove that air is added to water when it tumbles over rocks?
7. Why is oxygen in this experiment "used up"?
8. Name the part of your experiment which represents the microorganisms.
9. Name the part of your experiment which represents the "sewage."
10. In which test tube did you have the most sewage? The least sewage?
11. Graph your results here.



12. What does the line you plotted tell you about the relationship between the amount of sewage in a body of water and the amount of oxygen in a body of water?
13. What effects would dumping large amounts of sewage into a river have on the dissolved oxygen in the water?
14. Some bacteria, given ample food and water, can multiply every 20 minutes or so. Compute the number of bacteria that would be present in eight hours (starting from one bacteria cell) at this rate. Example: in 20 minutes there would be two bacteria; in 40 minutes, four; in 60 minutes, eight bacteria, etc.
15. **Extra Credit:** Go to the library and look up two diseases associated with polluted water. Write a paragraph about each disease.

Name ______________________________ Hour ________

Experiment 2: Thermal Pollution

GENERAL: In this experiment you will determine how water temperatures affect the speed at which microorganisms use oxygen. We'll use the same yeast-milk-methylene blue system as in *Experiment 1*, with these modifications:

1. Each test tube will contain *the same* amount of biodegradable waste (milk).
2. Each test tube will contain *the same* amount of decay organisms (yeast).
3. Each test tube will be exposed to a *different* temperature. As you can see, the *variable* in this experiment is *temperature!*

MATERIALS

Same materials as for *Experiment 1*, plus a thermometer and a heat source (alcohol lamp or bunsen burner)

DIRECTIONS

1. Place about 150 mL of water in two 250 mL beakers . . . or put about "two inches" of water in the bottom of two small pans. The amount of water isn't critical because you're simply making "water baths."
2. Heat the water in one beaker or pan to a temperature of 37 degrees Celsius (body temperature). When the water reaches 37 degrees, remove the beaker from the heat source and set it aside.
3. Place the second beaker on the burner stand and heat it to 100 degrees Celsius (boiling).
4. Place two mL of milk in each of the three test tubes. Add three drops of methylene blue to each tube. Mix the contents of each tube the same way you did in *Experiment 1*.
5. Prepare a sample of yeast solution by adding two mL (about half a teaspoon) of yeast to 10 mL of water in a beaker or baby food jar. Mix the yeast and water with your stirring stick.
6. When the water in the second beaker has reached boiling, remove the beaker from the heat source and set it aside.
7. Add two mL of yeast solution to each of the three test tubes and mix the contents of each tube the same way you did in *Experiment 1*.
8. Set one test tube into the beaker of near boiling water, one test tube into the warm (37 degrees Celsius) water, and put one test tube into a rack at room temperature on your table. RECORD THE EXACT TIME YOU STARTED THE EXPERIMENT (placed the tubes in water) IN THE TABLE BELOW.

Test Tube	Temperature	Time of Starting	Time Color Changed to White	Total Time for Color Change to Occur (minutes)
1	Room			
2	37°C			
3	100°C			

9. Record in the table the time each tube changed from *blue* to *white*.

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(Continued on back)

QUESTIONS

1. If a fish needs a lot of oxygen, would you expect to find it living in cold water or warm water? Why?
2. Chemical reactions speed up when temperatures are increased. How would raising the temperature of a river affect the metabolism of fish and aquatic organisms that live there?
3. If a fish were taken from cold water and placed in warm water, would it breathe faster or slower? Why?
4. A number of different results were possible in this experiment. Your "color changes" might have proceeded in this order:
    - a. Hot tube changed first, warm tube second, room temperature tube last.
    - b. Warm tube changed first, hot tube second, room temperature last.
    - c. Warm tube changed first, cold second, hot tube — *no color change!*

    Discuss each possible result with your classmates. Then explain *in detail* the probable reason for *each* result.

Name ______________________________ Hour __________

Experiment 3: Effects of Thermal Pollution on Fish Metabolism

GENERAL: In this experiment you will determine how thermal pollution affects the metabolism of living goldfish. Since you will be working very close to the thermal death point of your goldfish, it's essential that you follow directions carefully and complete the experiment quickly. This entire experiment should require no more than 15 minutes to complete!

MATERIALS

Two 600-mL beakers or equivalent sized jars
One laboratory specimen (or baby food) jar with tight-fitting lid
One laboratory thermometer
Small fish net
Bunsen burner, alcohol lamp, or hot water from the tap
Demineralized water (necessary only if your tap water is chlorinated)

DIRECTIONS

1. Label two beakers A and B, and fill each one about two-thirds full of water.
2. Fill the specimen jar with water and add a goldfish to it. Cap the jar tightly and make sure there are no air leaks.
3. Set the baby food jar into container A.
4. Record the temperature of the water in container A in the chart below.

Container	Temperature, °C.	15-Second Counts	Average
A		1. ________ 2. ________ 3. ________ 4. ________	
B	40°C	1. ________ 2. ________ 3. ________ 4. ________	

5. Next, determine the respiratory rate of the fish by counting the number of times it opens and closes its mouth in 15 seconds. Take *four* 15-second counts and record the value of each count in the table. When you have completed the experiment, *average* the four counts.

   While you're counting, your partner should heat the water in container B to 40 degrees Celsius. When your thermometer reads exactly 40 degrees, remove the beaker from the heat source and set it aside.
6. Remove the jar which contains the fish from container A and place it into container B.
7. Give the fish about 20 seconds to adjust to the warmer water; then take four 15-second "breathing" counts. Average the numbers as in No. 5 above. (If the first count disagrees with the others by a large amount, disregard it; it may simply mean your fish has not adjusted to the temperature of the water yet.) If the counts decrease — such as 32, 25, 18, 12 — your fish is dying! Stop the experiment immediately and return your fish to the rest tank. Repeat the experiment with a new fish.
8. As soon as you have finished the experiment, return your fish to the rest tank.

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(Continued on back)

QUESTIONS

1. Did the fish use more oxygen in warm water or cold water?
2. Fish are cold-blooded. (Their temperature matches the temperature of their environment.) With this fact in mind, what might happen if a cold water fish like a salmon was accidentally placed in a warm lake? Could the fish survive? What would happen to the respiration rate of the fish?
3. Study the "temperature table" on page 26 of the **Water Quality Factors** pamphlet; then answer these questions:
   a. What is the average "survival temperature" of the fish in the table? Determine this by averaging the Celsius temperatures in column 2.
   b. Assume that all the fish with a "survival temperature" *less* then the average value you calculated above live in cold water . . . and those with a "survival temperature" greater than this value live in warm water. Make a table similar to the one below and list *each fish* in the appropriate place.
4. Assume you're the manager of a fish pond in a city park. You've been asked to stock the pond with three species of fish which might best survive the warm summer temperatures often occurring in shallow park ponds. What three fish would you select? Give reasons for your answers.

Cold Water Fish	**Warm Water Fish**

Name ______________________ Hour ________

Experiment 4: Measuring the Amount of Dissolved Oxygen in a Water Sample

Students: Study the section on *Dissolved Oxygen* and *Percent Saturation of Oxygen* in the **Water Quality Factors** pamphlet *before* you begin this experiment!

GENERAL: In this experiment you will use Hach *Dissolved Oxygen* Test Kits to determine precisely how much dissolved oxygen is in water samples of different temperatures. You will use the *Saturation Monogram* on page 13 of the **Water Quality Factors** pamphlet to compute the percent saturation of oxygen.

MATERIALS

Hach Dissolved Oxygen Test Kit, or Water Ecology Test Kit
Celsius thermometer
Ice cold water
Water heated to 25-30 degrees Celsius
Saturation Monogram
Pint size (or larger) bottle with tight-fitting cap

DIRECTIONS

1. Identify the following parts of the Dissolved Oxygen Test Kit.

   Sample bottle (a round bottle with a ground glass stopper)

   Titration flask (a square bottle). When you "titrate" you add one solution — a drop at a time — to another until the color changes. The *titrant* solution in this experiment is the PAO solution in the square plastic bottle.

   Plastic measuring tube — The plastic measuring tube holds exactly 5.8 mL of fluid when it is filled *level full.*

   Powder pillows — These are sealed plastic tubes containing premeasured chemicals. There are three different kinds of powder pillows in this kit: *Dissolved Oxygen 1, Dissolved Oxygen 2,* and *Dissolved Oxygen 3.* The number 1 and 2 pillows look alike; don't mix them up!

Caution: Powder pillows contain ingredients which are poisonous if swallowed! Do not taste any of the chemicals in the powder pillows!

2. Fill the sample bottle *level full* with *ice-cold* tap water and determine the temperature of the water with a thermometer. Record the temperature in the table.
3. Close the bottle with the ground glass stopper (some water will overflow). There must not be any air bubbles in the bottle.
4. Follow the directions in the cover of the kit to perform the test for dissolved oxygen. Record your results in the table. DIRECTIONS MUST BE FOLLOWED *EXACTLY* OR YOU WON'T GET CORRECT RESULTS. SO READ EACH STEP CAREFULLY AND DON'T LEAVE OUT ANY PROCEDURES!
5. Repeat the experiment with water that has been heated to 25-30 degrees Celsius (no hotter). Be sure you record the temperature of the warm water in the table before you begin.

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6. Fill a pint-sized or larger bottle about two-thirds full of ice-cold water. Stopper the bottle and shake it vigorously for 30 seconds. Then pour the water into your sample bottle and test it for dissolved oxygen as you did before. Be sure you record the temperature of the water in the table before you begin.
7. When you have completed the experiment, clean your equipment and return it to the test kit. Bring the test kit to your teacher for a final check.
8. Use the **Saturation Monogram** (see page 13 of **Water Quality Factors** pamphlet) to compute the percent saturation of oxygen in each of the three samples. Record this information in the table.

QUESTIONS

1. Which of the three water samples had the most oxygen? Can you offer an explanation why?
2. Which of the three samples contained the least amount of dissolved oxygen? Can you offer an explanation why?
3. How does a *ppm* differ from a *mg/L*?
4. Is it possible for warm water to contain more dissolved oxygen than cold water? How?
5. How would the ecology of a river be affected if a factory dumped warm water directly into it.

	Ice Water	**Warm Water**	**Aerated Water**
Temperature			
Dissolved Oxygen (mg/L)			
Percent Saturation			

Name ______________________________ Hour __________

Experiment 5: Determining Number of Coliform Bacteria in a Water Sample

(These instructions are for teacher use.)

GENERAL: The Presumptive and Confirmed MPN (most probable number) Tests commonly used to determine the presence of coliform bacteria are too unwieldy for use in most junior/senior high schools. Teachers need fast and easy methods requiring a minimum amount of equipment and preparation. Here are two suitable coliform tests.

Quantitative Test Using Membrane Filtration Equipment

MATERIALS

Membrane filtration apparatus
Hand-operated vacuum pump
MF-Endo broth in premeasured 2 mL ampules
Absorbent media pads and gridded membrane filters
50- or 60-mm (about 2-inch) diameter petri dishes
1 mL plastic pipet
Sterile or dechlorinated tap water

DIRECTIONS

Teacher: Go over the procedures for using the membrane filtration equipment with your students. Directions below only apply to making the *total* coliform test.

1. Light the alcohol lamp and sterilize the forceps by dipping in alcohol and igniting by passing the tip through the flame.
2. Use the sterilized forceps to place a white absorbent media pad into a petri dish. Break an ampule of MF-Endo medium and pour the contents onto the absorbent pad. Close the petri dish.
3. Resterilize the forceps in the flame. Then use it to place a *gridded* membrane filter on the filter funnel. Close the apparatus.
4. Pour about 100 mL (the amount makes no difference) of sterile or chlorine-free tap water into the funnel of the machine. The sterile water is used to dilute the test sample so coliforms (if present) will be distributed evenly on the filter and, therefore, easier to count.
5. Pipet one mL of the "test sample" (river or stream water) into the funnel of the apparatus. Students should not put the pipet to their mouths: The pipet will fill by capillary action if it is held vertically in the water, or a pipet bulb may be used.
6. Cover the apparatus and swirl it to mix the sterile dilution water and the one-mL test sample.
7. Attach the hand pump to the equipment and filter the water. Sterilize the forceps. Then remove the filter and set it into the petri dish on top of the MF-Endo saturated pad. Close the petri dish.
8. Store the dish *upside down* in a dark place at room temperature for 48 hours or incubate at 35 degrees Celsius for 24 hours. (Petri dishes are incubated in an inverted position to prevent condensate or moisture from falling on bacterial colonies; it causes them to "run together.")
9. *Counting the coliforms:* Coliform colonies have a distinct *metallic green* sheen. Count only the obvious coliforms. Then multiply the colony count by 100 to relate the information to the established standards in the **Water Quality Factors** pamphlet.

AFTER THE EXPERIMENT: Admonish students not to touch the filters during the clean-up process. Used filters and pads should be handled with forceps. Filters and pads are best disposed of in a large tin can filled with a mixture of three parts water and one part household bleach. Later, the contents of the can are flushed down the toilet.

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(Continued on back)

Wash plastic petri dishes in hot soapy water. Then place them on paper toweling to dry. Then, drop them (open) into a gallon jar of 70 percent alcohol. (This is the same as "rubbing" alcohol.) Sterilized dishes can be left in the alcohol for weeks or months until needed; then students can fish them out, drain on clean paper toweling and reassemble for use. Plastic petri dishes seem to have an unlimited life span if treated in this manner.

Students should wash their hands *thoroughly* after handling the petri dishes to prevent any chance of illness. A good way to complete the activity is to have students rinse their hands in a *weak* bleach/ water solution.

Optional Method for Determining the Presence of Coliform Bacteria

Here's a convenient way to test for the "quantitative" presence of coliform bacteria without using an expensive membrane filtration kit.

MATERIALS

Sterile glass or plastic petri dishes. [Either 50- or 60-mm (2-inch) diameter or 100-mm (4-inch) diameter dishes may be used; the 100-mm dishes are easiest to work with.] Glass (*not* plastic) petri dishes may be sterilized in a pressure cooker (autoclave) at 15 pounds pressure for 15 minutes or in a dry oven at 350 degrees Fahrenheit for three hours. Either type may be sterilized by dipping in 70 percent alcohol for 30 minutes.

1 mL plastic pipet
EMB (eosin-methylene-blue) agar

DIRECTIONS

1. Make up one or more sterile EMB agar plates per group.
2. If you are using 100-mm sized petri dishes, pipet 1 mL of test sample (river or lake water) directly into the dish. Cover the dish and swirl the sample so the water covers as much agar as possible. [If small (50- or 60-mm) petri dishes are used, the pipetted volume of samples will have to be reduced to avoid "flooding" the plates. About 0.2 to 0.3 mL should work, but you may need to do some experimentation to determine the ideal sample size for your equipment.]
3. Store the petri dish *upside down* in a warm dark place for 48 hours or incubate at 35 degrees Celsius for 24 hours.
4. The presence of *metallic green* colonies is a positive test for coliform bacteria. Count the coliform colonies and compare your results to the established standards given in the **Water Quality Factors** pamphlet.

   Note: Due to crowding of the bacteria, it may be impossible to count all the colonies. Nevertheless, this experiment will give students a rough idea of the relative numbers of coliforms present in the water sample. Though relatively inaccurate, this procedure is fast, simple and very inexpensive. In addition, it requires a minimum of equipment. Even if students don't find coliforms, they will discover other kinds of bacteria, which in itself is interesting.

Name ______________________________ Hour __________

Experiment 6: Velocity and Volume

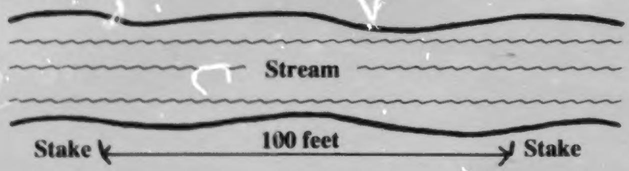
MATERIALS

- 100-foot measuring tape or rope graduated in one-foot increments
- 2 wooden stakes
- Small stick
- Watch with second hand
- Graph paper
- Yardstick
- Pencil
- Hip boots or waders

DIRECTIONS

To determine the velocity of a stream:

1. Measure off a 100-foot distance along the shore line of the stream and mark each end of the distance with wooden stakes.



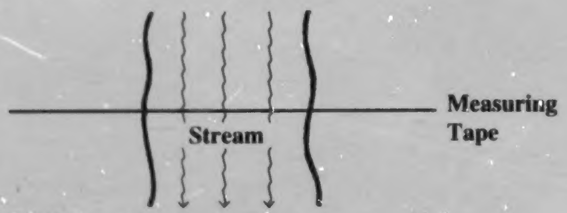
2. Toss a stick into midstream and determine (to the nearest second) how long it takes to float the 100-foot distance. Repeat this procedure two more times. Then *average* the three counts. Report your information in the table below:

Trials	Time (seconds) Required to Float 100 Feet
1	
2	
3	
Average =	

3. Calculate the *velocity* (speed) of the river in *feet per second* by dividing 100 feet by the **average** time. Average velocity = ____ feet/second

To determine the volume of the stream:

1. "Calibrate" a piece of graph paper to match the margins of the sample *stream profile*. "Depth in inches" should be written along the left vertical margin and "width of stream in feet" should be written along the bottom horizontal margin. Prepare a different piece of graph paper in this manner for each of the three stream profiles you will make.
2. Stretch a measuring tape or calibrated rope tightly across the stream.



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(Continued)

3. Walk across the stream and measure the water depth (use the yardstick) at one-foot intervals. "Call off the depth" as you measure so that a friend on shore may plot it on the graph.
4. When you have completed your measurements there will be a series of dots on your graph which will correspond to the irregular depth of the stream bottom. Connect these dots (see sample *stream profile)* and you'll have an accurate picture of the stream bottom.
5. Make two other stream profiles at selected places along the stream.
6. When you return to class, compute the *area* of each profile as follows:
   a. Add up the number of squares inside the diagram (shown as the *unshaded* part of the sample *stream profile*). Partial squares should be added to other partial squares. For example: half a square plus half a square equals one full square.
   b. Enter the total number of squares counted in the table below:

Profile	**Number of Squares Counted**
1	
2	
3	
Total squares =	
Total squares divided by 3 =	**= Average**
Average squares divided by 12 =	**= Area (in ft^2)**

   c. Total the squares, compute the **average** and divide the average by 12. The result will equal the average area of the river in square feet (ft^2). Enter the information in the table.
7. Work through the following formula using the information above:

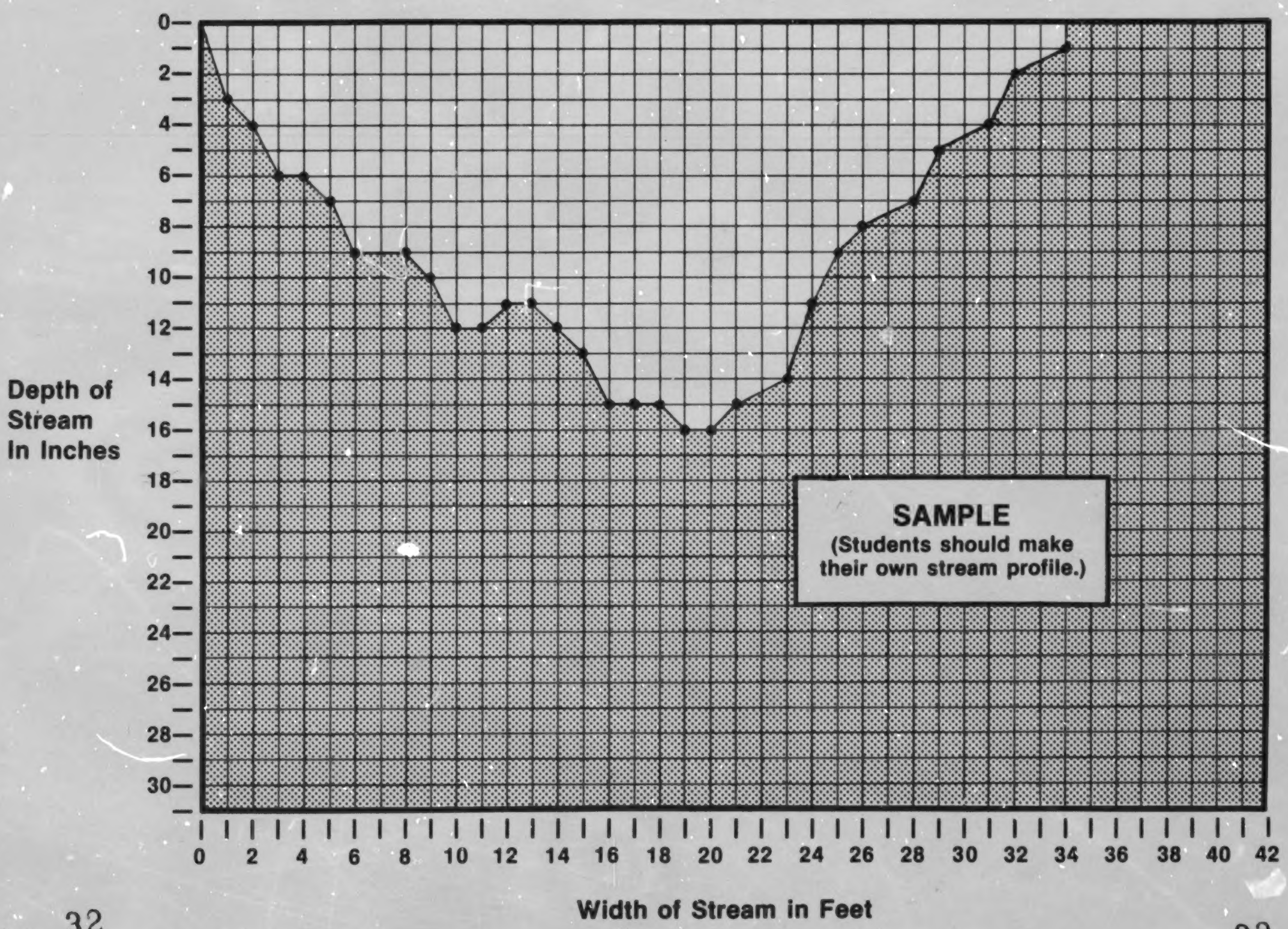
(1)	______ Area in square feet	×	______ Velocity in feet per second	=	______ Volume of river in cubic feet per second (ft^3/sec)	**(2)**
(2)	______ Cubic ft/sec of flow	×	7.5 Number of gallons in 1 cubic foot of water	=	______ Gallons of water per second	**(3)**
(3)	______ Gallons of water per second	×	60 Number of seconds in a minute	=	______ Flow rate in gallons of water per minute	**(4)**
(4)	______ Flow rate (gallons/minute)	×	1,440 Number of minutes in 24 hours	=	Total amount of water which flows downstream each day (gallons)	**(5)**

QUESTIONS

1. If each person uses about 100 gallons of water per day (not counting industrial use), how many people could live off the water which flows down this stream?
2. What would happen to the ecology of this area if all the water in the stream were pumped out for use by people?
3. How much water do you think could be withdrawn safely from this stream without affecting the ecology of the area?
4. What is the main source of water (rain, ground water, lake flowage or other) for this stream?
5. Where does the water you drink come from?
6. Could this stream be used to suppy the water needs of your community? Why or why not?

Stream Profile *Sample*

(See Experiment 6)



SAMPLE

(Students should make their own stream profile.)

Experiment 6

Name ______________________________ Hour __________

Directions for Writing the Lab Report

General: These directions must be followed carefully. Reports won't be accepted if they're not prepared according to these directions!

Rules

1. Each group submits *one* report.
2. Reports must be stapled and have a cover of heavy paper or plastic. Only the test names —and the names of the people who performed them — should appear on the cover of the report.
3. All work must be written neatly in pen or typed. If you can't write clearly . . . PRINT!
4. Art work should be included in the report only if it makes the information clearer or easier to understand. Pretty drawings have no place in a scientific report if they serve no purpose.

How to Write the Report

Divide your report into the following sections:

Introduction

Under this heading, write a paragraph or so explaining what you did, where you went, and why. Tell the tests you performed and the equipment you used.

Test Background Information

List each test your group performed, along with the name of the person who performed it. For example: "Dissolved Oxygen," by Gerry Goodkid.

Gerry Goodkid should then read all the information in the **Water Quality Factors** pamphlet pertaining to *dissolved oxygen*. He should then write a neat, accurate summary of what he read!

Spelling and composition are very important. So read what you write after you write it!

Results

This is simply your table of test results. Include a simple map of the river that shows where the tests were made.

Questions

Students who determined *velocity, volume* and *stream profile* have some questions to answer. No one else has to do this section.

Conclusion

End your report with a section entitled "conclusion." Every group will tabulate its results on the board. Study these results. Then . . . 1. Look up the values in the **Water Quality Factors** pamphlet . . . and 2. Talk to other groups who performed the tests. When you understand what the numbers on the board mean, you will have a complete picture of the quality of water in the river.

Now you're ready to write the conclusion. Simply summarize what you learned by reading and talking to students from other groups. Stick to facts such as: "The pH may be too low for fish to reproduce here." Don't get carried away and say, "The river is dying!"

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Jacobson

Water, Water Everywhere, But...

Water Quality Factors

Reference Unit—First Edition

HACH

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Reference
Unit

First Edition

WATER, WATER EVERYWHERE, BUT . . . . .

WATER QUALITY FACTORS

By Cliff Jacobson

Teacher of Environmental Science
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Hastings, Minnesota

Technical Editing by:

Josephine W. Boyd

Senior Technical Editor
Hach Company
Loveland, Colorado

Students: *Do not* read any of the pages in this booklet until you have read the **Student Reading Unit**

Hach Company
Loveland, Colorado 80539

WATER, WATER EVERYWHERE, BUT . . . .

Water Quality Factors

By Cliff Jacobson
Technical Editing by Josephine W. Boyd

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Dr. Boyd has worked on various biological and chemical problems of water supply and wastewater disposal in arctic areas of the North American and European continents as well as in municipal systems in temperate areas. She is a member of a number of professional societies and has extensive experience as a writer for both popular and scientific publications.

Water Quality Factors

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Water Quality Factors

A Note to the Teacher . . . . . The information contained within these pages has been researched carefully. However, in a few cases it has been necessary to sacrifice extreme accuracy in order for students in grades 7-10 to achieve a basic understanding of the concepts involved. *Everything* has been written with the assumption that students *have no background in chemistry and only a limited knowledge of mathematics and general science*. This premise necessarily complicates what can and cannot be included here.

For these reasons, the information contained within this pamphlet should be used *for instructional purposes only*. Each "quality factor" is affected by variables too complex to discuss intelligently within the knowledge framework of this age level.

WATER QUALITY FACTORS is not intended for use as "text material." It is a *reference* work to be used by students while interpreting their water test results.

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WATER QUALITY FACTORS

Carbon Dioxide (CO_2)

Carbon dioxide is an odorless, colorless gas produced when animals and bacteria **respire.** All animals and many bacteria utilize oxygen and release carbon dioxide. Green plants in turn absorb the carbon dioxide and, by the process of photosynthesis, produce oxygen and carbon-rich foods. The general formula for photosynthesis is summarized below:

Respiration and "breathing" are not the same. Respiration is the exchange of oxygen and carbon dioxide in the cells of living things. "Breathing" implies the use of lungs to bring the oxygen in — and force the carbon dioxide out — of an organism's body.

Photosynthesis

$$\text{Carbon dioxide + Water} \xrightarrow[\text{light and chlorophyll}]{\text{In the presence of}} \text{Oxygen + Carbon-rich foods}$$

Respiration

$$\text{Carbon-rich foods + Oxygen} \longrightarrow \text{Carbon dioxide + Water.}$$

Green plants carry on photosynthesis *only* in the presence of light. At night, they *respire* and burn the food they made during the day. Consequently, more oxygen is used and more carbon dioxide enters waterways at night than during the daytime. When carbon dioxide levels are high and oxygen levels are low, fish have trouble respiring (taking up oxygen), and their problems become worse as water temperatures rise. As you can see from the table below,* even small amounts of carbon dioxide can affect fish:

Amount of CO_2 (mg/L)	Effects on fish
1.0-6.0	Fish avoid these waters.
12	Few fresh water fish can survive for long periods of time in water with a carbon dioxide level greater than this.
30	Kills the most sensitive fish immediately
45	Maximum limit for trout
Above 50	Trout eggs won't hatch.

mg/L (milligrams per liter): One mg/L equals one part per million (ppm).

It's lucky for fish that "free" carbon dioxide (free means not combined with anything) levels rarely exceed 20 mg/L because most fish are able to get used to this much carbon dioxide without bad effects.

When several days of heavy cloud cover occur, plants respire during the day as well as at night. When that happens in a pond containing lots of plant life, fish can be hurt in two ways: by low dissolved oxygen and by high carbon dioxide.

Carbon dioxide quickly combines in water to form carbonic acid, a weak acid. The presence of carbonic acid in waterways may be good or bad depending on the pH of the water. If the water is alkaline (high pH), the carbonic acid will act to neutralize it. But if the water is already quite acid (low pH), the carbonic acid will only make things worse by making it even more acid.

---

*Summarized from a number of research studies. Information from *Water Quality Criteria*, California Water Quality Control Board, 1963, and *Water Quality Criteria, 1972*, Environmental Studies Board, National Academy of Sciences, Washington, D.C., 1972.

Chlorine

Chlorine is a greenish-yellow, poisonous gas that dissolves easily in water. It's a common **disinfectant** used in sewage treatment plants, city water works and swimming pools. Chlorine is used widely as a bleaching agent in textile factories and paper mills and it's an important ingredient in many laundry bleaches.

A **disinfectant** is a chemical substance that kills bacteria.

Free chlorine (chlorine gas that is dissolved in water) is poisonous to fish and aquatic organisms even in very small amounts. (See the table on page 3.) However, its dangers are relatively short-lived compared to the dangers of most other highly poisonous substances. Free chlorine combines with decaying materials to form compounds called **Trihalomethanes** or THMs. THMs are very poisonous and they're **carcinogenic** to people. Unlike free chlorine, THMs are very persistent — they may pose a health threat to living things that will last a long time.

Chloroform is a **trihalomethane** or THM.

Carcinogenic means the substance will cause cancer.

Thus, the dangers of chlorine come from two sources: 1. the short term effects of the dissolved gas, and 2. the long term effects of the poisonous THM compounds. The *free* chlorine test measures only the amount of free or dissolved chlorine in the water. The *total* chlorine test measures both free and combined forms of chlorine.

Less than one-half (0.5) **mg/L** of free chlorine is needed to kill bacteria without causing water to smell or taste bad. Most people can't detect the presence of chlorine in water at double (1.0 mg/L) that amount. Although 1.0 mg/L chlorine is not harmful to people, it does cause serious problems for fish.

mg/L (milligram per liter): One mg/L equals one ppm (part per million).

Effects of Chlorine on Industrial Processes

Chlorine may cause canned or frozen food to taste "funny." It also may affect the smoothness or brightness of plated metals. Chlorine levels as low as 0.3 mg/L can spoil the quality of high-grade paper during the manufacturing process.

Water Used for Irrigation

The concentration of chlorine in city water or treated wastewater rarely reaches one mg/L (ppm). So chlorine usually is not a problem to farmers and gardeners using either city water or wastewater to irrigate their crops.

Effects on Fish and Aquatic Life

The table on page 3 shows how chlorine affects fish and aquatic organisms. It's important to realize chlorine becomes *more* poisonous as the **pH** level of the water drops. And it becomes even more poisonous when it is combined with other poisonous substances such as cyanides, **phenols** and ammonia.

pH: See the discussion of pH in the **Student Reading Unit.**

Phenols are organic chemicals produced when coal and wood are distilled and when oil is refined. Phenols are found in a number of products — from organic wastes to sheep dip. Athough phenols are *very* poisonous, dilute solutions of a phenol (carbolic acid) are used as a disinfectant.

(Continued on page 3)

Effects of Chlorine on Fish and Aquatic Organisms*

Amount of *total* chlorine (mg/L)	Effects on fish and aquatic organisms
0.37	Maximum fish can tolerate
0.25	Only the hardiest fish can survive.
0.05	Maximum amount which can be tolerated by young Pacific salmon in the ocean
0.02	Maximum amount Brook Trout and Brown Trout can withstand
0.01	Recommended maximum for all fish and aquatic life
0.01	Kills Chinook Salmon and Coho Salmon
0.006	Kills trout fry in two days
0.1	Kills most **marine plankton**
0.01-0.05	Oysters have difficulty pumping water through their bodies.
1.0	Kills oysters

Plankton are microscopic plants and animals which live in water. **Marine** means "in the ocean."

*Summarized from a number of research studies. Main reference: Quality Criteria for Water, U.S. EPA., July, 1976.

Chlorides

Chlorides are salts containing chlorine and a metal. Some common chlorides are sodium chloride (table salt), calcium chloride and magnesium chloride. The Hach Chloride Test Kit measures the total amount of chlorides of all kinds.

Chlorides are found in nearly all rivers, lakes and streams. They may get into water from rocks containing chlorides, from sea water contamination of water supplies, from farm fertilizer run-off, or from the wastewater of paper-making and galvanizing processes, water softening operations, oil wells and refineries. Small amounts of chlorides are essential for life; they pass through your digestive system unchanged and become a part of raw sewage.

Chlorides usually are not harmful to people. It is the *sodium* part of table salt (sodium chloride) that has been linked to heart and kidney disease. Perhaps you know someone who is on a "salt-free" diet for this reason.

mg/L means milligrams per liter: One mg/L equals one part per million (ppm).

Sodium chloride may impart a salty taste to water at concentrations as low as 250 **mg/L,** but most people can't detect calcium or magnesium chloride until levels reach 1000 mg/L. The U.S. Public Health Service recommends chlorides not exceed 250 mg/L in water used for drinking. These standards have been established for reasons of taste rather than health.

Other agencies and foreign countries have also set limits for chlorides. The recommended values are summarized below:*

Water Use	Maximum Amount of Chlorides
Public drinking water	250 mg/L
Water used by industries	50 mg/L
Irrigation	100 mg/L
Livestock and wildlife	1500 mg/L

Salt corrodes metals and spoils the taste of some foods. For this reason, many industries cannot use water that contains large amounts of chlorides. Recommended limits are given below:

Industry or Process	Maximum Amount of Chlorides
Brewing	100 mg/L
Making carbonated beverages	250 mg/L
Dairy industry	30 mg/L
Paper making (ground-wood pulp process)	75 mg/L
Making steel	175 mg/L
Making sugar	20 mg/L
Textile processes	100 mg/L

*Information for the tables was obtained from *Water Quality Criteria*, California Water Quality Control Board, 1963.

(Continued on page 5)

Fish and Aquatic Life

Most good fishing waters have a chloride concentration of less than 170 mg/L. The table below shows the effects of chlorides on fish:

Chloride Concentrations Above These Values Are Deadly to Fish

Concentration of chlorides in mg/L	Species of Fish
400	Trout
2000	Some fish
4000	Bass, pike, perch
4500-6000	Carp eggs
8100-10,500	Small bluegills

Chromium

Chromium, one of the most abundant elements on earth, is found in soil, air and some foods. It is used widely in a number of industrial processes — from plating metals and anodizing aluminum to making dyes, explosives, paper and paints. While *small* amounts of chromium are essential for the life of people and animals, large amounts of it may be poisonous and even **carcinogenic.**

Carcinogenic substances can cause cancer.

Chromium exists in several chemical forms, but the human body can use only the "trivalent" form. The "hexavalent" form — which gets into water through industrial wastes from metal-plating operations and factory cooling towers where it is used to prevent metal corrosion — is most poisonous.

Standards

mg/L (milligrams per liter): One mg/L equals one ppm (part per million).

U.S. Public Health Service rules state no more than 0.05 **mg/L** of hexavalent chromium (called "chromate") may be present in public drinking water supplies. All available research indicates this amount provides an adequate margin of safety for humans. When scientists studied the effects of chromium on one family who drank water containing 0.45 mg/L of hexavalent chromium for three years, they could find no unfavorable effects on their health. Other studies indicate people are able to safely drink water which contains as much as 5.0 mg/L of chromate.

Although small amounts of chromium are necessary for the life of humans and animals, there is no evidence that chromium is essential for the growth or well-being of plants. In fact, "hexavalent" chromium is poisonous to plants even in amounts as low as 2-3 mg/L.

Fish appear to be relatively tolerant of moderate levels of chromium. At least 10 mg/L of hexavalent chromium are needed to harm most fish, while very hearty species like bluegills, goldfish and sunfish may withstand 50 mg/L of hexavalent chromium or more!

Trout and salmon are the fish most sensitive to chromium pollution. Just 0.2 mg/L of chromate will reduce the growth and cause death of Chinook Salmon. Brown Trout begin to die when chromate levels reach about 7 mg/L. Silver Salmon die when amounts reach 10 mg/L.

Zooplankton are microscopic *animals* which live in water.

Zooplankton are much more susceptible to the effects of chromate poisoning than are fish. Many forms of these tiny animals are killed when chromate levels exceed 0.1 mg/L.

Summary of Recommendations

Drinking water standards: A maximum of 0.05 mg/L of hexavalent chromium (chromate).

Fish and wildlife: It is recommended that levels of chromate in rivers and lakes not exceed 0.1 mg/L. As little as 0.003 mg/L of chromate may indicate the presence of industrial pollution.

Coliform Bacteria

Bacteria are classified into four major groups according to their feeding habits.

1. *Saprophytic* — these feed on dead **organic** matter and are commonly called "decomposers." Saprophytic bacteria play a significant role in water polluted with biodegradable wastes because they use up great amounts of oxygen as they break down the wastes.

Organic wastes all contain carbon. Anything that is biodegradable (once part of a living thing) is organic.

2. *Commensal* — Commensal bacteria take food from a living organism but in the process provide a valuable service to that organism. For example, bacteria present in the intestines of humans assist in the digestion of many foods. These bacteria couldn't live without us and, indeed, we would have difficulty digesting our food without them!

3. *Parasitic* — Parasites live off another organism at the expense of its health. All **pathogenic** bacteria fall into this category.

4. *Autotrophic* — These bacteria make their own food from simpler **inorganic** substances. Some autotrophic bacteria contain chlorophyll and can carry on photosynthesis.

Pathogenic organisms are those which "cause disease."

Inorganic compounds do not contain carbon.

Autotrophic bacteria live in water or soil containing iron and sulfate compounds. The end products produced by the bacteria lower the pH (make it more acid) of water and soil. This may harm some plants and animals. Because potatoes like an acid soil, potato growers often add sulfur to their soil so sulfur bacteria (autotrophs) will lower its pH.

Pathogenic bacteria are our greatest concern because of the health problems they pose. Unfortunately, pathogens are hard to detect in water because: 1. There usually aren't very many of them, and 2. They can't survive for very long outside the warm confines of the human or animal body. Nevertheless, if pathogens get into a water supply from animal wastes or through the release of unprocessed toilet wastes, they may live long enough to find and infect a human or animal.

Even if we could test easily for the presence of pathogens in water it would not be a good idea because we might get sick from exposure to the harmful bacteria. For this reason, we test for the presence of a relatively harmless (commensal) form of bacteria, called **coliform** bacteria which, like pathogens, can live in the human body.

Coliform: a relatively harmless bacteria found in the human intestine (colon).

Coliform bacteria are common in the intestines of both warm- and cold-blooded animals and aid in the digestion of foods. When animals "relieve themselves," some of these coliform bacteria (and pathogenic **microbes,** too, if present) pass out of their bodies with the waste. If these wastes find their way into a water supply, they will bring the bacteria and other microbes with them.

Microbes are too small to be seen without a microscope. They include bacteria, algae and tiny animals called *protozoa.*

Consequently, if we find coliform bacteria in a water sample we can presume there also is human or animal **excrement** — and in all probability, pathogens — there, too. Large numbers of coliform organisms therefore indicate the possible presence of pathogens.

Excrement is body waste. What goes down the toilet is "excrement."

As previously mentioned, coliform bacteria are found in the intestines of warm and cold-blooded animals. However, cold-blooded animals don't carry the same diseases as warm-blooded ones. For this reason, the **APHA** requires a special *fecal* test be used to separate out those bacteria found in the gut of warm-blooded animals.

APHA is the American Public Health Association.

(Continued on page 8)

Coliform Bacteria

The *fecal* test is easy to do but requires precise incubation temperatures — 44.5 degrees Celsius and not varying more than 0.2 degrees Celsius either way. Consequently, we'll use the less-temperature dependent *total* test to determine the presence of coliform bacteria in our experiments. The specifics of the Total Coliform Test are explained in *Experiment 5,* which you may obtain from your teacher.

Coliform Standards

EPA is the U.S. Environmental Protection Agency.

Coliform standards for drinking water are given below. They are the same for all the states and are administered by the **EPA.** Standards for swimming waters and other recreational uses generally are set by the states and are close to the limits given below:

For drinking water: No more than one *total* coliform per 100 milliliters (mL) of water tested.

For swimming pools: Same as drinking water — no more than one total coliform per 100 mL of water tested. (This is the standard for swimming pools in Colorado and is similar to the standard for many other states.)

For "primary contact" waters (swimming beaches): An average of no more than 200 *fecal* coliforms per 100 mL. (Some states use 1000 *total* coliforms per 100 mL sample.)

For boating and general enjoyment (not swimming): The standard usually used is the one recommended by the Committee on Water Quality Criteria for the U.S. Secretary of the Interior — an average of no more than 2000 *fecal* coliforms per 100 mL of water tested. (*Total* coliform numbers will be *much* higher.)

The above standards are taken from Colorado's "Water Quality Standards" and *Water Pollution Microbiology.** Use them to interpret your coliform bacteria findings according to the procedures outlined in *Experiment 5.*

Pathogens are organisms which cause disease.

A weak positive relationship exists between the number of total (or fecal) coliform bacteria in a swimming area and your chances of getting sick. In fresh water, 2000 to 3000 total coliform bacteria per 100 mL water may increase your chances of becoming ill. However, most of the illnesses among swimmers are diseases of the eye, ear, nose and throat and are *not* the result of coliform bacteria or intestinal **pathogens.** This information suggests that we need better tests than the total coliform and fecal coliform tests when we check swimming pools and bathing beaches!

USPHS is the United States Public Health Service.

Is it safer to swim in sewage-infested salt water than in sewage-infested fresh water? Evidently, yes. The **USPHS** discovered that bathing in sewage-polluted sea water carries only a negligible risk to health, even when measured coliform counts are over 10,000 per 100 mL water sample. Possibly the salt concentration of sea water kills many of the harmful bacteria. Also, oceans are big places — they quickly dilute the sewage to harmless levels. Your chances of encountering pathogens even in relatively crowded ocean waters are remote.

Water Pollution Microbiology, edited by Ralph Mitchell. Published by Wiley-Interscience, a Division of John Wiley & Sons, Inc., New York, 1972.

Dissolved Oxygen

"Dissolved oxygen" is oxygen that is dissolved in water. It gets there by *diffusion from the surrounding air,* by *aeration of water which has tumbled over falls and rapids* and as a waste *product of photosynthesis.* An oversimplified formula for photosynthesis is given below:

$$\underset{(CO_2)}{\text{Carbon dioxide}} + \underset{(H_2O)}{\text{Water}} \xrightarrow{\text{In the presence of light and chlorophyll}} \underset{(O_2)}{\text{Oxygen}} + \underset{(C_6H_{12}O_6)}{\text{Sugar}}$$

Fish and **aquatic** animals *cannot* split oxygen from water (H_2O) or other oxygen-containing compounds. Only green plants and some bacteria can do that through photosynthesis and similar processes. Virtually all the oxygen we breathe is manufactured by green plants. A total of three-fourths of the earth's oxygen supply is produced by **phytoplankton** in the oceans.

Aquatic animals are those that live in water.

Phytoplankton are tiny algae (plants) that live in the water.

If there is not enough oxygen in a water supply, it may be because the water is too warm, or because there are too many bacteria or aquatic animals in the area. If aquatic animals don't have enough **predators** to keep their numbers down, they will overpopulate and use great amounts of dissolved oxygen.

Predators hunt other animals for food.

Oxygen levels also can be reduced through overfertilization of water plants by run-off from farm fields which contain phosphates and nitrates (the ingredients in fertilizers). Under these conditions, the numbers and size of water plants increase a great deal. Then, if the weather becomes cloudy for several days, **respiring** plants will use much of the available dissolved oxygen. When the increased numbers of water plants eventually die, they become food for bacteria, which in turn multiply and use large amounts of oxygen. (See the discussion of *eutrophication* in the **Student Reading Unit**.)

Respiration uses oxygen and produces carbon dioxide.

The amount of dissolved oxygen an aquatic organism needs depends upon its species, the temperature of the water, pollutants present, the physical state of the organism and more! Consequently, it's impossible to accurately predict minimum dissolved oxygen levels for specific fish and aquatic animals.

For example, at 5 degrees Celsius (41 degrees Fahrenheit), trout use about 50-60 milligrams (mg) of oxygen per hour; at 25 degrees Celsius (77 degrees Fahrenheit), they may need five or six times that amount. Fish are cold-blooded animals; they use more oxygen at higher temperatures because their **metabolic** rate increases — that is, the chemical processes in their bodies speed up.

Metabolism is all the chemical processes which take place in your body.

Nevertheless, numerous scientific studies suggest the minimum amount of dissolved oxygen that will support a large population of many different kinds of fish is from 4-5 **parts per million** (ppm). Good fishing waters generally average about 9.0 parts per million (ppm) of dissolved oxygen.

A **part per million** (ppm) and milligram per liter (mg/L) are the same thing!

When dissolved oxygen levels drop below about 3.0 parts per million, even the rough fish die. The table on page 10 shows some representative comparisons:

(Continued on page 10)

Fish*

	The lowest amount of dissolved oxygen at which fish survived for 24 hours (summer)	The lowest amount of dissolved oxygen at which fish survived for 48 hours (winter)
Northern Pike	6.0 mg/L	3.1 mg/L
Black Bass	5.5 mg/L	4.7 mg/L
Common sunfish	4.2 mg/L	1.4 mg/L
Yellow Perch	4.2 mg/L	4.7 mg/L
Black Bullhead	3.3 mg/L	1.1 mg/L

How Dissolved Oxygen Affects Water Supplies

A lot of dissolved oxygen in a community water supply is good because it makes drinking water taste better. However, large amounts of dissolved oxygen speed up corrosion in water pipes. For this reason, industries use water with the least possible amount of dissolved oxygen. For example, water used in very low pressure boilers should have no more than 2.0 parts per million of dissolved oxygen but most boiler plant operators try to keep oxygen levels to 0.007 ppm or less!

Testing for Dissolved Oxygen

You may test a water supply for dissolved oxygen with an electronic meter or a chemical test kit. The meter is faster and easier to use than the kit, but it's also much more expensive.

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*From *Water Quality Criteria*, The Resources Agency of California, State Water Quality Control Board, 1963. Publication No. 3-A.

Percent Saturation of Oxygen

A dissolved oxygen test (using a kit or meter) tells precisely how much oxygen is dissolved in the water. But it does not tell you how much dissolved oxygen the water is *capable of holding* at the temperature it was tested.

As you have already learned, water temperature affects not only the **metabolism** of cold-blooded animals (and all fish are cold-blooded), but also the amount of oxygen which can dissolve in water. The table shows the relationship: The warmer the water is, the less the dissolved oxygen, and vice versa. As you can see, it's no accident that fish requiring a lot of oxygen are found in cold water.

Metabolism is all the chemical processes which take place in your body.

When water holds all the dissolved oxygen it can hold at a given temperature, it is said to be 100 percent saturated with oxygen. If water holds *half as much* oxygen as it can hold at a given temperature, it is 50 percent saturated.

You can determine "percent saturation" with the aid of a thermometer, dissolved oxygen test kit or meter, and a saturation monogram like the one shown on page 13. Instructions for using the saturation monogram are given on page 12.

It is possible to have a condition of *supersaturation* — that is, water holds *more* oxygen than it is supposed to be able to hold at a given temperature. Supersaturation may result when water is tumbled over rapids and falls (the "white" in white water is air!). But conditions of supersaturation usually don't last long. Because tiny air bubbles rise to the surface of the water and "pop," the percent saturation soon drops to 100 percent or less.

However, supersaturation, even for short periods of time, can be very harmful to fish. In ponds at 150 percent saturation, carp had a higher percentage of disease than where saturation levels were below 125 percent. In Westlake Park, Los Angeles, Calif., fish died when saturation levels reached 300 percent!

Supersaturation is a common problem along rivers controlled by dams. There are two ways fish can get downstream around a dam: They may go through the churning turbine blades of the electrical generators and possibly be ground to a pulp by the spinning fans, or they may go over the spillway with the spring runoff. Some survive the fall; others don't. Those that live often die of "gas bubble disease."

Gas bubble disease is common in the spring when huge volumes of rain water overfill the reservoir above the dam and flow violently over the spillway. When this water falls over the dam, it becomes highly aerated (well-mixed with air). Fish at the base of the dam get a supercharged dose of air in their bloodstream. Many fish die — practically explode! — from the gas bubbles formed in their bodies.

For purposes of experimentation, we'll apply the following percent saturation figures:

125 percent or more — too high, may be dangerous to fish!
80-124 percent — excellent!
60-79 percent — okay, but not great
Below 60 percent — poor. Either the water is too warm or a lot of bacteria are using up precious oxygen.

(Continued on page 12)

Percent Saturation of Oxygen

Solubility means the amount that can dissolve. If something is *soluble* in water, it can dissolve in water. If it's *insoluble*, it can't dissolve.

mg/L (milligram per liter) and ppm (parts per million) are the same thing.

Solubility of Dissolved Oxygen in Water

Temperature Degrees C mg/L	Solubility mg/L	Temperature Degrees C mg/L	Solubility mg/L
0	14.6	16	10.0
1	14.2	17	9.8
2	13.8	18	9.6
3	13.5	19	9.4
4	13.1	20	9.2
5	12.8	21	9.0
6	12.5	22	8.9
7	12.2	23	8.7
8	11.9	24	8.6
9	11.6	25	8.4
10	11.3	26	8.2
11	11.1	27	8.1
12	10.9	28	7.9
13	10.6	29	7.8
14	10.4	30	7.7
15	10.2		

How to Use the Saturation Monogram

1.Determine the temperature in degrees Celsius of your water sample at the scale on top of the chart. Put a dot with your pencil on this point.

2. Find the amount of dissolved oxygen* in mg/L on the bottom of the chart and put a dot here. Draw a straight line between the two points (or place a straightedge across them).

3. Read the percent saturation of your water sample off the scale marked *percent saturation.*

> Example: A water sample taken at 15 degrees Celsius that contains 11 mg/L of dissolved oxygen would be about 110 percent saturated. According to the saturation information given on page 11, that value would be "excellent" because it lies between 80 and 124 percent.

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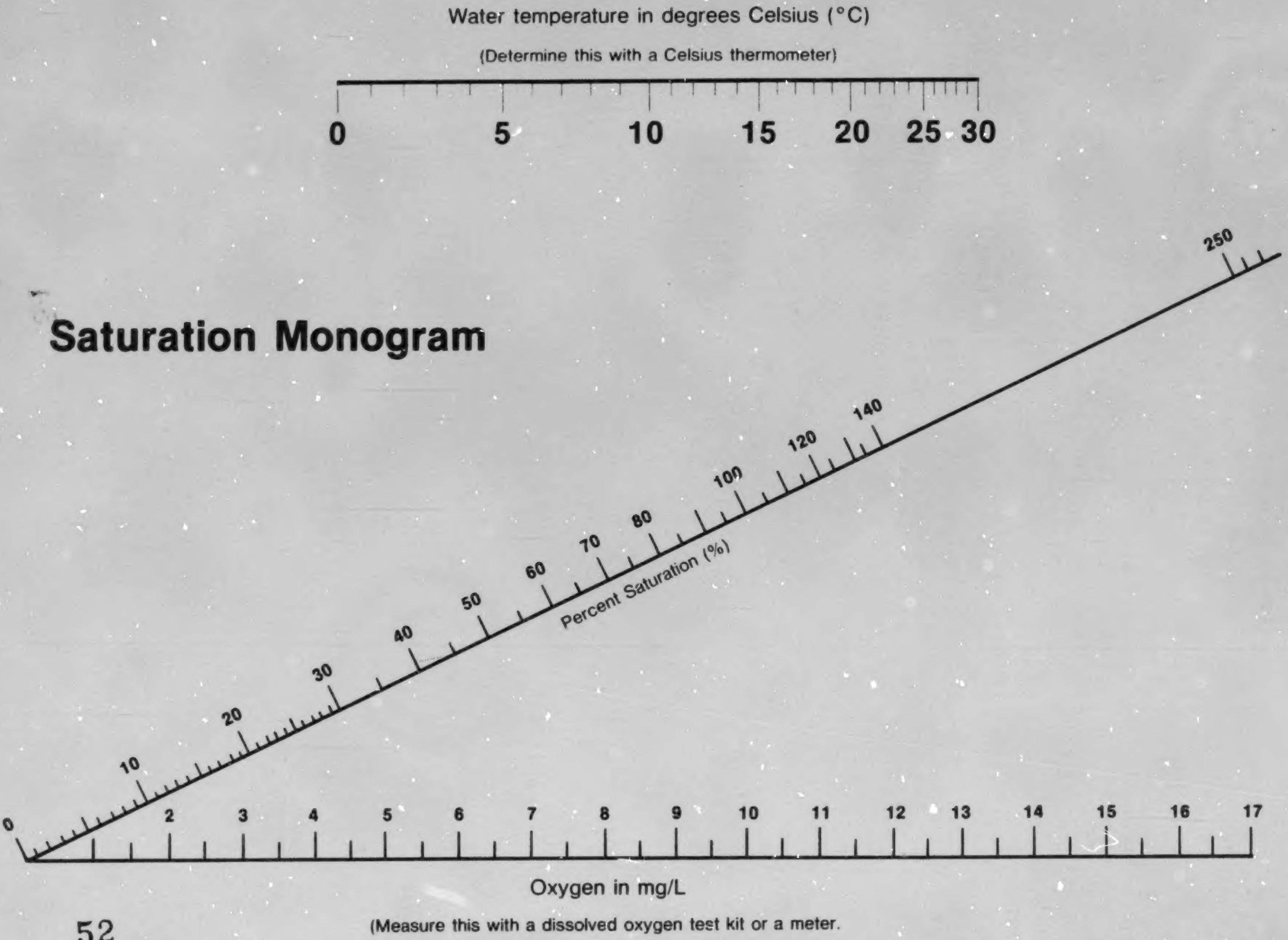
*The amount of dissolved oxygen in milligrams per liter (mg/L) is determined with a dissolved oxygen test kit or electronic meter. One milligram per liter (mg/L) equals one part per million (ppm).

(Continued on page 13)

Saturation Monogram



Five-Day Biochemical Oxygen Demand (BOD) Test

The *biochemical oxygen demand (BOD)* test gives you a rough indication of the amount of biodegradable waste in a water sample. If water contains a lot of biodegradable matter, it probably also contains a lot of bacteria, a condition which translates into low dissolved oxygen levels. (Remember, bacteria feed on biodegradable materials and utilize oxygen when they **respire.**)

Respiration is the process whereby animals take in oxygen and give off carbon dioxide.

A high "BOD" indicates a polluted situation; a low BOD suggests the opposite. If a town or industry dumps sewage into a water supply, the effect of that dumping — in terms of lowered dissolved oxygen levels — may not show up for several hours or days. A simple dissolved oxygen test like the one you performed in *Experiment 4* will indicate only the amount of dissolved oxygen in the water *at the time of testing.* The BOD test, however, includes the long term effects of biodegradable wastes on dissolved oxygen and therefore gives a more accurate picture of the water's quality.

Though specialized equipment is used by water technologists to measure BOD, a close approximation of BOD values can be obtained by the following procedure:

Five-Day BOD Test — Procedure

mL is the metric symbol for milliliter: 250 mL equals about half a pint or one cup.

1. Fill a *clean* 250 **mL** or larger bottle or jar about three-fourths full with the water to be tested.
2. Shake the water vigorously for about 30 seconds.
3. Determine the amount of dissolved oxygen in the bottle by using a Hach Dissolved Oxygen Test Kit and record this information in your notebook.
4. Pour the water from the large jar or bottle into a smaller stoppered bottle. Fill the stoppered bottle *completely* so there are no air bubbles. Place the stoppered bottle in a warm (about 20 degrees Celsius or 68 degrees Fahrenheit) dark room for five days (120 hours).
5. At the end of the five-day period, determine the amount of dissolved oxygen in the water sample using the Hach Dissolved Oxygen Test Kit.
6. Subtract the value obtained from day five from that obtained on day one. The result is the FIVE-DAY BOD.

Example: Day one dissolved oxygen equals 14 mg/L
Day five dissolved oxygen equals 6 mg/L
Five-day BOD equals . . . . 9 mg/L

Use the rough standards* below for interpreting your findings:

1-2 mg/L BOD	Very clean water, little biodegradable waste
3-5 mg/L BOD	Moderately clean water, some biodegradable waste
6-9 mg/L BOD	A lot of biodegradable matter, many bacteria
10 or more mg/L BOD	Very bad; someone may be dumping biodegradable wastes into the water.

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*These *are not* official standards. A fast-moving stream with lots of rapids probably can handle a BOD much higher than 10, whereas a slow-moving stream probably can't. It's important to consider these differences when you interpret your results.

Note: The BOD test won't work on waters containing substances poisonous to bacteria. For this reason, some sewage treatment plants perform the COD (chemical oxygen demand) test on their sewage. The COD test uses dangerous, concentrated acid and requires expensive equipment, so it is beyond the scope of student experiments.

Hardness

Originally, water was said to contain a lot of hardness ("hard" water) when soap would not lather easily. Now, hardness is defined as the amount of calcium and magnesium in the water because the two minerals are chiefly responsible for "hard water."*

The natural source of hardness usually is limestone rock which is dissolved by water that's been made acid by carbon dioxide. Carbon dioxide makes up 0.03 percent of air and is a waste product of human and animal respiration and of bacteria and other organisms in soil and water. When carbon dioxide combines with water, it forms a weak solution of carbonic acid — the same stuff that's in carbonated beverages. Carbonic acid eats away the limestone and produces calcium carbonate ($CaCO_3$) — a white scale compound which makes water hard. (When you get home, check the inside of your teakettle. If you see white scaly stuff, you are looking at calcium carbonate.)

Limestone is dissolved easily by carbonic acid. Granite isn't. For this reason, geographical areas rich in limestone usually have very hard water, whereas those which are mostly granite, don't.

The *total* hardness test is the test performed most frequently in the water industry. It measures the total amount of calcium and magnesium in the water and is expressed in metric units as *milligrams per liter* (mg/L) of calcium carbonate ($CaCO_3$), or in English units as *grains per gallon* (gpg) of calcium carbonate. Use the formula below to convert one unit to another:

$$\text{mg/L} = \text{gpg} \times 17.1 \quad \text{or} \quad \text{gpg} = \frac{\text{mg/L}}{17.1}$$

Some total hardness values and their effects are shown in Tables 1 and 2.

Table 1†

Total Hardness (in milligrams per liter of calcium carbonate)	**Description**
0 to 60	Soft water
61 to 120	Moderately hard water
121 to 180	Hard water
181 and up	Very hard water

There's an important relationship between the amount of carbonates in water and the amount of "bicarbonates," which are similar compounds. Bicarbonates function like Alka-Seltzer® to buffer water against acids. Thus, if a waterway has a high carbonate content (total hardness), it also has good buffering ability and is less likely to be hurt by acid rain and acid wastes.

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*Iron, aluminum, manganese and other minerals also may cause "hardness" if enough of them are present in the water. However, large amounts of these minerals usually are not found in natural waters.

†From *Study and Interpretation of the Chemical Characteristics of Natural Water*, Geological Survey Water-Supply Paper 1473, 1970.

(Continued on page 16)

Hardness

Effects on Living Organisms

Toxic substances are poisonous.

Soft water makes heavy metals like mercury, copper and lead more poisonous to fish. Nonmetals such as ammonia, phenols and certain acids also seem to be much more **toxic** to fish in soft water than in hard water. There is some evidence that drinking soft water over long periods of time may increase your chances of getting a heart attack.

Effects on Industrial Water Supplies

In the baking industry, very soft water produces sticky bread dough and soggy bread. On the other hand, hard water used for cooking toughens many vegetables and it slows the speed of fermentation — the process by which cheese and beer are made.

The range of recommended hardness values for water used by industries is summarized in Table 2.

Beans, peas and alfalfa are members of the **legume** group of plants.

Table 2*

Name of Industry and Process	Total Hardness (mg/L $CaCO_3$)
Brewing beer	200 to 300
Making carbonated beverages	200 to 250
Water used for cooling	50
Food canning and freezing:	
general . .	50 to 85
legumes . .	25 to 75
fruits and vegetables . .	100 to 200
peas . .	200 to 400
General food processing	10 to 250
Washing clothes	0 to 50
Steel manufacturing	50
Making synthetic rubber	50

*From *Water Quality Criteria*, California Water Quality Control Board, 1963.

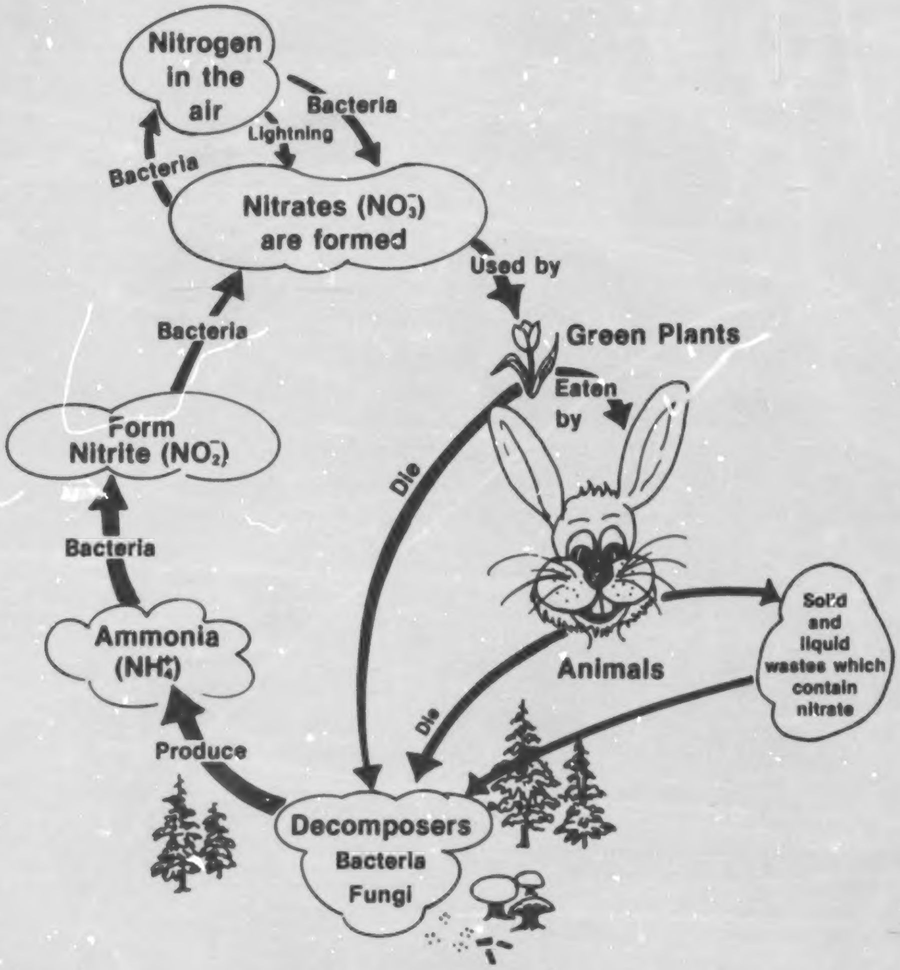
Nitrates and Nitrites

Nitrogen makes up about 80 percent of the air we breathe. It's an essential **component** of proteins and is found in the cells of all living things. **Inorganic** nitrogen may exist in the "free" state as a gas, or as *nitrites, nitrates* or *ammonia;* **organic** nitrogen is found in proteins and other compounds. Nitrogen is recycled continually by plants and animals. See the *Nitrogen Cycle* below:

A **component** is a "part" of something.

Inorganic compounds do *not* contain carbon; **organic** compounds do.

The Nitrogen Cycle


Nitrogen in the air
Bacteria
Lightning
Bacteria
Nitrates (NO_3^-) are formed
Used by
Green Plants
Eaten by
Bacteria
Form Nitrite (NO_2^-)
Die
Bacteria
Solid and liquid wastes which contain nitrate
Ammonia (NH_3)
Animals
Die
Produce
Decomposers
Bacteria
Fungi

Nitrates and Nitrites

Sources of Nitrates and Nitrites

Plankton are microscopic plants and animals which live in water.

Nitrate is a major ingredient in farm fertilizer. When it rains, varying amounts of this chemical wash from farm land into nearby waterways. The nitrates stimulate the growth of **plankton** and water weeds which provide food for fish. This may cause an increase in the fish population. However, if algae grow too wildly, oxygen levels in the water will be reduced and fish will die. (See the discussion of *eutrophication* in the **Student Reading Unit**.)

Nitrates and **nitrites** are not the same. Spelling is important!

Nitrates also may get into waterways from lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, animal wastes (including fish and birds) and discharges from car exhausts. In nature, they generally are formed by the action of bacteria on ammonia and on compounds which contain nitrogen. **Nitrites** are relatively short-lived because they're quickly converted to **nitrates** by bacteria. However . . . nitrites produce a serious illness (brown blood disease) in fish even though they don't exist for very long in the environment. Nitrites also react directly with hemoglobin in the blood of people to produce *methemoglobin* which destroys the ability of blood cells to transport oxygen. This condition is especially serious in babies under three months of age as it causes a condition known as methemoglobinemia or "blue baby" disease. Many babies have been seriously posioned by well water containing more than 10 mg/L of *nitrate* nitrogen. Since nitrates may be reduced to poisonous *nitrites* in the human intestine, the U.S. Public Health Service has established a level of 10 mg/L of *nitrate*-nitrogen as the maximum amount allowable in public drinking water supplies. Water with *nitrite* levels exceeding 1.0 mg/L should not be used for feeding babies. Nitrite concentrations in drinking water seldom exceed 0.1 mg/L.

Fish and Aquatic Life

Nitrate-nitrogen levels below 90 mg/L and nitrite levels below 0.5 mg/L seem to have no effect on warm-water fish. But salmon and other cold-water fish are more sensitive. The recommended nitrite minimum for salmon is 0.06 mg/L.

Ammonia

(See the discussion of nitrates and nitrites on pages 17 and 18.)

Pure ammonia is a strong-smelling colorless gas. It's manufactured synthetically from nitrogen and hydrogen or is produced from coal gas. In nature, ammonia is formed by the action of bacteria on proteins and urea. The *Nitrogen Cycle* on page 17 shows the relationship.

Ammonia makes a powerful cleaning agent when mixed with water. For this reason, it is one of the most common industrial and household chemicals.

The formula for ammonia, NH_3, means it consists of one atom of nitrogen and three atoms of hydrogen. Because ammonia is so rich in nitrogen it makes an excellent fertilizer. In fact, **ammonium** salts are a major source of nitrogen for fertilizers. Like nitrates, ammonia may speed the process of **eutrophication** in waterways.

Ammonium is a form of ammonia. It's formula is NH_4^+.

See the discussion of **eutrophication** in the **Student Reading Unit.**

Ammonia is very poisonous to fish and aquatic organisms even in very low **concentrations.** When levels reach 0.06 **mg/L**, fish can suffer gill damage and when levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. At around 2.0 mg/L, tolerant fish like carp begin to die. Ammonia levels greater than about 0.1 mg/L usually indicate polluted waters.

Concentration means "amount."

mg/L (milligrams per liter): One mg/L equals one ppm (part per million).

The dangers ammonia poses for fish depend in large part on the temperature and pH of the water and the amount of dissolved oxygen and carbon dioxide present. Remember the higher the pH, the more poisonous the ammonia and the warmer the water, the greater the **toxicity** of ammonia. And . . ammonia is much more poisonous to fish and aquatic life when water contains very little dissolved oxygen and carbon dioxide.

Toxicity means poisoning ability.

pH

See the Acid Rain section of the **Student Reading Unit** for an elementary discussion of pH.

Effects of pH on Fish and Aquatic Life

Most fish can tolerate pH values of about 5.0 to 9.0 but, if you're a serious fisherman, you'll look for waters which fall between pH 6.5 and 8.2. The vast majority of American rivers, lakes and streams fall within this range.

Some specific effects of pH on fish and aquatic life are summarized in the table below:*

Limiting pH Values		
Minimum	**Maximum**	**Effects of Some Scientific Studies**
3.8	10.0	Fish eggs could be hatched, but deformed young were often produced.
4.0	10.1	Limits for the most resistant fish species
4.1	9.5	Range tolerated by trout
4.3	---	Carp died in five days.
4.5	9.0	Trout eggs and larvae develop normally.
4.6	9.5	Limits for perch
5.0	---	Limits for stickleback fish
5.0	9.0	Tolerable range for most fish
---	8.7	Upper limit for good fishing waters
5.4	11.4	Fish avoided waters beyond these limits.
6.0	7.2	Optimum (best) range for fish eggs
1.0	---	Mosquito larvae were destroyed at this pH value.
3.3	4.7	Mosquito larve lived within this range.
7.5	8.4	Best range for the growth of algae

The pH of a body of water is affected by its age and by the chemicals dumped into it by communities and industries. Most lakes are basic (alkaline) when they are first formed and become more **acidic** with time due to the build-up of **organic** material in the water. As organic substances decay, carbon dioxide (CO_2) forms and combines with water to produce a weak acid, called "carbonic" acid — the same stuff that's in carbonated soft drinks. Large amounts of carbonic acid lower the pH of the water.

Acidic means "acid."

Organic materials all contain carbon. Anything that is biodegradable is organic.

Synergistic Effects of pH

Synergy is the process whereby two or more substances combine and produce effects greater than their sum. For example, 2 + 2 = 4 (mathematically). But

Synergistically is an adjective; **synergy** is a noun. Both words mean the same thing.

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*From *Water Quality Criteria*, California Water Quality Control Board, 1963.

(Continued on page 21)

synergistically, 2 + 2 = *much more* than 4! Synergy is a mathematical impossibility but it is a chemical reality. Here's how it works:

When acid waters (waters with low pH values) come into contact with certain chemicals and metals, they often make them more poisonous than normal. As an example, fish that usually can withstand pH values as low as 4.8 will die at pH 5.5 *if* the water they're swimming in contains as little as 0.9 **mg/L** of iron. Mix an acid water environment with small amounts of aluminum, lead or mercury, and you have a similar problem — one which far exceeds the usual dangers of these substances.

mg/L (milligram per liter): This is the same as a part per million (ppm).

Sea (salt) water is not as susceptible as fresh water to pollution by acid wastes. This is because the different salts in sea water tend to **buffer** the water with Alka-Seltzer-like ingredients. Normal pH values in sea water run around 8.1 at the surface and decrease to about 7.7 in deep water. Many types of shellfish and algae are more sensitive than fish to large changes in pH, so they need the relatively stable (for pH) environment of the sea to survive.*

Buffer: a substance which can neutralize an acid or base without its own nature being changed in the process.

Effects of pH on Water Supplies

The table below shows how pH affects different industrial processes:†

Recommended pH Values

Industrial Process	Minimum	Range
Brewing beer		6.5-7.0
Food canning and freezing	7.5	---
Washing clothes	---	6.0-6.8
Rayon manufacturing	---	7.8-8.3
Steel making	---	6.8-7.0
Tanning leather	---	6.0-8.0

---

*Shallow waters in subtropical regions, which have a lot of organic matter, often range from pH 9.5 in the daytime to 7.3 at night. Evidently, organisms living there are either able to tolerate these extremes in pH or can swim to more neutral waters.

†From *Water Quality Criteria*, California Water Quality Board, 1963.

Alkalinity

Read the discussion of pH before you read Alkalinity!

Read about **buffers** in the Student Reading Unit.

Alkalinity is not a pollutant. It is a measure of the sum total of all the substances in water which have "acid-combining" ability. Don't confuse *alkalinity* with pH. pH measures the strength of an acid or base; alkalinity indicates the power of a solution to *react* with acid and **"buffer"** its pH — that is, the power to keep its pH from changing.

For example: Absolutely pure water has a pH of exactly 7.0. It contains no acids, no bases and no (zero) alkalinity. On the other hand, a buffered water at pH 6.0 can have high alkalinity. If you add a small amount of weak acid to both water samples, the distilled water will change its pH instantly (become more acid). But the *buffered water* won't change its pH easily because the Alka-Seltzer-like buffers present will absorb the acid and keep it from "expressing itself."

Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes waters less susceptible to the effects of acid rain and acid wastes. The main sources of natural alkalinity are rocks which contain carbonate, bicarbonate and hydroxide compounds. Borates, silicates and phosphates also may contribute to alkalinity.

For example: Limestone is rich in carbonates, so waters flowing through limestone regions generally have high alkalinity — hence good buffering capacity. Conversely, granite does not have the minerals which contribute to alkalinity. Therefore, areas rich in granite have low alkalinity and, therefore, poor buffering capacity.

mg/L (milligrams per liter): One mg/L equals one ppm (part per million).

It's generally agreed the best waters for fish and aquatic organisms are those with pH values between 7 and 8, with a total alkalinity of 100-120 **mg/L**. This amount of alkalinity is enough to protect fish against any sudden changes in pH.

It is possible to increase the alkalinity of a lake or pond by simply adding lime to it. Of course, this is practical only for small lakes.

Some recommended alkalinity values are indicated below:*

Industry and Process	Recommended Maximum Total Alkalinity in mg/L as Calcium Carbonate
Brewing beer	
— light beer	75-80
— dark beer	80-150
Carbonated beverages	85
Food products (canning)	300
Fruit juice	100
Washing diapers	60
Pulp and paper making (ground-wood process)	150
Rayon manufacture	50
Tanning hides	135
Textile mill products	50-200
Petroleum refining	500

*This information is summarized from *Water Quality Criteria*, California Water Resources Board, 1963 . . . and *Quality Criteria for Water*, U.S. EPA, July, 1976.

Phosphates

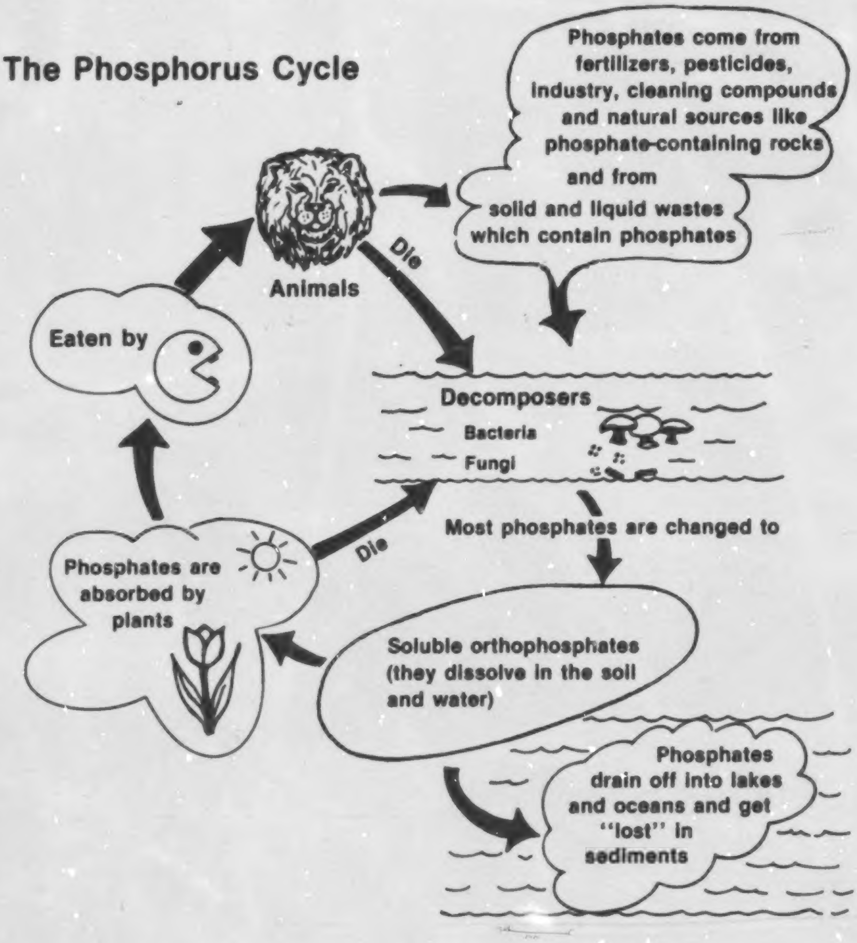
Phosphorus is one of the key elements necessary for the growth of plants and animals. Nearly all fertilizers contain **phosphates.** When it rains, varying amounts of phosphates wash from farm soils into nearby waterways. The phosphates stimulate the growth of **plankton** and water plants which provide food for fish. This may cause an increase in the fish population and a general improvement in the quality of life of the waterway. However, if too much phosphate is present the algae and water weeds will grow wildly, may choke the waterway, and use up large amounts of precious oxygen. The result may be the death of many fish and aquatic organisms. (See the discussion of *eutrophication* in the **Student Reading Unit**.

Phosphates are chemical compounds containing the element phosphorus.

Plankton are microscopic plants and animals which live in water.

The *Phosphorus Cycle* is said to be "imperfect" because not all phosphates are recycled. Some simply drain off into lakes and oceans and become lost in sediments. However, the "loss" of some phosphates is not serious because new phosphates continually enter the environment from other sources.

The Phosphorus Cycle


Phosphates come from fertilizers, pesticides, industry, cleaning compounds and natural sources like phosphate-containing rocks
and from
solid and liquid wastes which contain phosphates
Animals
Die
Eaten by
Decomposers
Bacteria
Fungi
Most phosphates are changed to
Die
Phosphates are absorbed by plants
Soluble orthophosphates (they dissolve in the soil and water)
Phosphates drain off into lakes and oceans and get "lost" in sediments

(Continued on page 24)

Phosphates

Phosphates enter waterways from human and animal wastes (the human body releases about a pound of phosphorus per year), phosphate-rich rocks, wastes from laundries, cleaning and industrial processes, and farm fertilizers. Phosphates also are used widely in power plant boilers to prevent corrosion and the formation of scale.

Effects on Humans

Phosphates won't hurt people or animals unless they're present in *very high* amounts. Even then, they'll probably do little more than interfere with digestion. It's doubtful that humans or animals will encounter enough phosphate in natural waters to cause any health problems.

Forms of Phosphate

Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorus in a different chemical formula. *Ortho* forms are produced by natural processes and are found in sewage. *Poly* forms are used for treating boiler waters and in detergents; they can change to the ortho form in water. *Organic phosphates* are important in nature and also may result from the breakdown of organic pesticides which contain phosphates.

The Hach Company makes kits that will test for the presence of the various phosphate types. However, you'll probably use the simple "cube" kit, which measures the most common form — orthophosphate — or the "color disc," which determines both orthophosphate and metaphosphate. There also is a "total" phosphate kit available to test for the presence of all three types of phosphates.

Some values for *total* phosphate phosphorus are given below.*

Amount of *total* phosphate-phosphorus	**Effects**
0.025 mg/L	Accelerates the eutrophication process in lakes
0.1 mg/L	Recommended maximum for rivers and streams
0.01-0.03 mg/L	Amount of phosphate phosphorus in most uncontaminated lakes

*If an orthophosphate "test cube" or an ortho/metaphosphate "color disc" gives you values above the total phosphate-phosphorus values given above, there's cause for concern.

Temperature

Variables which affect the temperature of waterways include:

1. *The color of the water.* Most of the heat which warms surface waters comes from the sun, so waterways with dark-colored water, or those with dark muddy bottoms, absorb heat best.

2. *The depth of the water.* Deep waters usually are colder than shallow waters simply because they require more time to warm up.

3. *The amount of shade received from shore line vegetation.* Trees overhanging a lake shore or river bank reduce the amount of sunlight (and warmth) which reaches the water. Some narrow creeks and streams are almost completely covered with overhanging vegetation during certain times of the year. The shade provided by this vegetation keeps water temperatures from rising too fast on bright sunny days.

4. *The latitude of the waterway.* Lakes and rivers in cold climates are naturally colder than those in warm climates.

5. *The time of year.* The temperature of waterways varies with the seasons.

6. *The temperature of the water which supplies the waterway.* Some lakes and rivers are fed by cold mountain streams or underground springs. Others are supplied by rain and/or surface run-off. The temperature of the water flowing into a lake, river or stream helps determine its temperature.

7. *The volume of the water.* The more water there is, the longer it will take to heat up.

8. *The temperature of effluents dumped into the water.* When man dumps heated **effluents** into waterways, the effluents raise the temperature of the water.

Fish and most aquatic organisms are cold-blooded. Consequently, their **metabolism** increases as the water warms and decreases as it cools. Each species of aquatic organism has its own optimum (best) water temperature. If the water temperature shifts too far from the optimum, the organism suffers. Cold-blooded animals can't survive temperatures below zero degrees Celsius (32 degrees Fahrenheit), and only "rough" fish like carp can tolerate temperatures much warmer than about 36 degrees Celsius (97 degrees Fahrenheit).

Fish can regulate their environment to some degree by swimming into water where temperatures are close to their requirements. Fish usually are attracted to warm water during the fall, winter and spring and to cool water in the summer. (Did you ever notice how fish swim down to cooler parts of the lake to escape the heat of the noonday sun?) Fish can sense very slight temperature differences. When temperatures exceed what they prefer by 1-3 degrees Celsius, they move elsewhere!

Fish migration often is linked to the temperature of the water they swim in. In early spring, rising water temperatures may "cue" fish to migrate to a new location or to begin their **spawning** runs. And the autumn drop in temperature spurs baby **marine** fish and shrimp to move from their nursery grounds in the **estuaries** out into the ocean, or into rivers, as the case may be. As you can see, all sorts of **physiological** changes take place in aquatic organisms when water temperatures change.

(Continued on page 26)

A **variable** is something which affects the outcome of an experiment.

Effluents are *out-flowing* liquids or discharges. The treated water flowing out of a sewage plant is an *effluent*. Some "advanced" waste treatment plants produce effluent clean enough to drink!

Metabolism is the sum of all the chemical processes which take place in your body.

Spawning means "to lay eggs."

Marine animals live in salt water.

Estuaries are places where rivers flow into the ocean. The water in estuaries is *brackish*, or "just a little bit" salty.

Physiology is the study of the chemistry and function of living things. For example: **Physiological changes** in people could be changes in their respiratory system, reproductive system or blood. When aquatic organisms have *physiological changes*, similar things happen — their "body chemistry" changes.

Temperature

The table below indicates how temperature affects some common species of fish.*

Species of Fish	Fish Won't Grow When It Gets Warmer Than This (C means Celsius, F is Fahrenheit, ° is degrees)	Maximum Temperature Fish Will Survive (---Indicates information unavailable)	Fish Won't Spawn (lay eggs) Above This Temperature	Fish Embryos Can't Survive Above This Temperature	Optimum or Preferred Temperature
	°C (°F)	°C (°F)	°C (°F)	°C (°F)	°C (°F)
Atlantic Salmon	20 (68)	23 (73)	5 (41)	11 (52)	---
Black Crappie	27 (81)	---	17 (63)	20 (68)	---
Bluegill	32 (90)	35 (95)	25 (77)	34 (93)	---
Brook Trout	19 (66)	24 (75)	9 (48)	13 (55)	---
Carp	---	36 (97)	21 (70)	33 (91)	32 (90)
Channel Catfish	32 (90)	35 (95)	27 (81)	29 (84)	---
Coho Salmon	18 (64)	24 (75)	10 (50)	13 (55)	20 (68)
Emerald Shiner	30 (86)	---	24 (75)	28 (82)	---
Lake Herring (Cisco)	17 (63)	25 (77)	8 (37)	8 (46)	---
Large Mouth Bass	32 (90)	34 (93)	21 (70)	27 (81)	23.5 (74)
Northern Pike	28 (82)	30 (86)	11 (52)	19 (66)	—
Rainbow Trout	19 (66)	24 (75)	8 (46)	15 (59)	13 (55)
Sauger	25 (77)	---	12 (54)	18 (64)	---
Small Mouth Bass	29 (84)	---	17 (63)	23 (73)	---
Sockeye Salmon	18 (64)	22 (72)	10 (50)	13 (55)	15 (59)
White Sucker	28 (82)	---	10 (50)	20 (68)	---
Yellow Perch	29 (84)	32 (89)	12 (54)	20 (68)	---

Teacher: Columns 1 and 2 are "example" calculated values for maximum weekly average temperatures for growth and short-term maxima for survival of fish during the summer. Columns 3 and 4 are a summary of reported values for maximum weekly average temperature for spawning and short-term maxima of embryo survival during the spawning season. From *Quality Criteria for Water*, EPA, July, 1976, and *Water Quality Criteria*, California Water Quality Control Board, 1963.

Diatoms are microscopic one-celled algae. Their cell walls are made of hard, glass-like material.

Many diatoms are beautiful. Scientists refer to diatoms as "algae which live in glass houses."

Fish are not the only organisms requiring specific temperatures. **Diatoms** seem to grow best at 15-25 degrees Celsius, green algae at 25-35 degrees Celsius, and blue-green algae at 30-40 degrees Celsius.

Warm water also makes some substances, such as cyanides, phenol, xylene and zinc more poisonous to aquatic animals. If high water temperatures are combined with low amounts of dissolved oxygen, the poisonous effects of these chemicals are made worse.

Detergents

If you've ever seen detergent foam floating down a river, you'll have to admit it's a pretty disgusting sight. Foaming occurs most frequently at rapids and points where sewage treatment plants dump wastes. On one occasion, detergents in River Lee, England covered an area of 1,500 square yards and built up to a height of 12 feet!

Under favorable conditions, a concentration of as little as 0.5 milligrams per liter (mg/L) will cause a slight froth to develop on the surface of a lake or river. Even when foaming does not occur, a detergent film may form on the water and prevent the exchange of oxygen and carbon dioxide. This obviously will affect the quality of life in the water.

Detergent scum also transports bacteria and other microorganisms greater distances than normally might be expected. In a sense, it allows microorganisms to "walk on water." For this reason, some scientists believe detergent levels are a better indicator of domestic pollution (pollution from household wastes) than are **coliform** bacteria. In one scientific study, water samples with 3-10 mg/L of detergents represented nearly five times as many unsafe waters (because of bacteria) as did waterways free of detergents.

Coliform bacteria are found in the human intestine. They indicate the possible presence of more harmful bacteria. See the discussion of coliform bacteria in this pamphlet.

Detergents also increase your chances of getting cancer because they put the cancer-causing agents (called carcinogens) into a form which can be utilized better by the human body.

Water begins to taste soapy to most people at a detergent concentration of 2 to 4 mg/L. As the concentration of detergents increases to about 12 mg/L, the water takes on additional "fishy" tastes. And if the water has been chlorinated (chlorine has been added), other terrible smells and tastes develop.

Effects on Fish

Large amounts of detergents will kill fish directly, while small amounts may simply injure their health. For example, one common detergent harms the gills of certain fish when it is present at a concentration of just over 5 mg/L. At concentrations of only 0.5 mg/L, it destroys the taste buds of some species of fish in just four weeks. At 10 mg/L, the destruction is accomplished in a single day! You can imagine what happens to the feeding habits of fish when they "lose" their taste buds.

Recommended Limits

The U.S. Public Health Service considers 0.5 mg/L of detergents to be the maximum permissible in drinking water. Above 0.5 mg/L, foaming will occur in tap water. Most fish can't live in water where the concentration of synthetic detergents exceeds 5 mg/L.

Turbidity

The American Public Health Association (APHA) defines turbidity as "the optical property of a water sample which causes light to be scattered and absorbed rather than transmitted in straight lines through the sample." In simpler terms, turbidity is a measure of "how cloudy the water is."

The ability of light to pass through water depends on how much suspended material is present. The *turbidity* may be caused by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals and coal dust. Any substance that makes water cloudy will cause turbidity. The most frequent causes of turbidity in lakes and rivers are soil erosion from logging, mining, and dredging operations and plankton.

Measuring Turbidity

The most accurate way to determine the turbidity of a water sample is with an electronic "turbidimeter." The turbidimeter is nothing more than a fancy photoelectric cell which accurately measures the amount of light scattered by turbidity particles when a light beam is aimed at the sample. The results are reported in special units called "Nephelometric Turbidity Units" or NTUs.

You also may measure turbidity by filtering a water sample and comparing its color (how light or dark it is) to a standard turbidity color chart.* You'll need the following equipment to do this: Gelman filter apparatus,† some white "membrane" filters and a standard color chart to compare your findings. Your teacher will show you how to operate the filter equipment and will provide a color chart.

The procedure for using the Gelman filter apparatus to determine the turbidity of a water sample is as follows:

1. Place a white gridded filter on the machine. You may handle the filter with your fingers; it's not necessary to use a sterilized tweezers.
2. Use a plastic cup or bucket to take a water sample from the river, lake or stream. Be sure you scoop *only the water,* not the sediment on the bottom.
3. Pour 100 milliliters (mL) of your water sample into the top of the machine. The unit is graduated in milliliters. Just fill it to the 100 mark.
4. Filter the sample. You may need to use a hand-operated vacuum pump to "pull" your sample through the filter.
5. Remove the filter from the machine and let it dry.
6. "Guesstimate" the turbidity of your sample by comparing its color to the color chart furnished by your teacher.
7. Refer to the information below for a discussion of what these values mean.

Drinking Water Standards

The APHA flatly specifies turbidity of drinking water shall not exceed five turbidity units and specifies one turbidity unit in many cases! However, some scientists think this standard is too generous. They want to see the value reduced to 0.1 units.

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*This *is not* a standard method for determining turbidity but it is reasonably accurate.

†***Teachers:*** If your school already has Millipore® or other brand membrane filtration equipment, it may be used in place of the Gelman equipment.

(Continued on page 29)

Industrial Use

The table below suggests turbidity limits for various industrial uses of water.*

Industrial Use	Maximum Turbidity Units
Beverages	1-2
Food products	10
Brewing beer	1-10
Water used in boilers	1-20 (varies with type of boiler)
Making high grade paper	5-25
Making rayon	1
Making cotton	25
Baking	10
Water used for cooling	50
Ice making	1-5 (same as drinking water)
Tanning leather	20

Effects of Turbidity on Fish and Aquatic Life

Turbidity affects fish and aquatic life by:

1. Interfering with the penetration of sunlight. Water plants need light for photosynthesis. If suspended particles "block out" light, photosynthesis — and the production of oxygen for fish and aquatic life — will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die. It's important to realize conditions which reduce photosynthesis in plants *increase* respiration, oxygen use and the amount of carbon dioxide produced. (Respiration is the *opposite* of photosynthesis. See the write-up on carbon dioxide in this pamphlet).

2. Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly.

3. Suspended particles may provide a place for harmful microorganisms to lodge. Some types of suspended particles actually may provide a "breeding ground" for bacteria.

4. Fish can't see very well in turbid water and so may have difficulty finding food. On the other hand, high turbidity units may make it easier for small fish to hide from larger predators.

The table below shows the amount of fish and **plankton** per acre which may be expected in ponds of different turbidities.

Plankton consists of microscopic plants and animals which live in water.

	Clear ponds	Intermediate ponds	Muddy ponds
Average turbidity units:	less than 25	25-100	over 100
Amount of fish in pounds per acre:	162	94	29
Comparative amount of plankton caught in nets:	12.8†	1.6	1

---

*This information is from *Water Quality Criteria*, California Water Quality Resources Board, 1963.

†The average amount of plankton netted in clear reservoirs is about 13 times greater than that caught in turbid reservoirs. What turbidity occurs in "clear" waters apparently comes from plankton, an excellent food for many varieties of fish.

Velocity and Volume

The speed at which a river moves is called its *velocity;* the amount of water it carries is its *volume.* The three main variables affecting velocity are: 1. how much the river drops per mile (usually expressed in feet), 2. how curvy the river is, and 3. the shape of the river's bottom (its *profile*).

Obviously, the steeper the drop, the faster the river moves. But less obvious is the shape of the river's bottom and how curves affect its flow. Other things being equal, a river with a smooth bottom will carry away sediments and water faster than a river with a rough, rocky bottom.

Curves slow down a river just like they slow down your car. The water on the outside of the curve moves faster than the water on the inside and thus erodes the outside bank and channel more rapidly than that on the inside. For this reason, rivers are always fastest and deepest on the outside bend — a good reason to stay away from these places in very high water (or to purposely seek them in low water) if you're swimming or boating.

For purposes of flood control, a straight, smooth bottom is best because it will carry water down stream most rapidly. However, a good habitat for fish and aquatic animals requires a rough bottom with lots of rocks, holes and submerged logs.

The velocity of a river can change from day to day or year to year. After a major rain, the velocity and volume usually increase. During a drought they decrease. Velocity also varies from point to point along a river. Usually, a river picks up speed where it narrows and loses speed where it widens. And curves, as stated, also affect velocity.

The procedures for determining the velocity and volume of a river are explained in *Experiment 6* which you may obtain from your teacher.

APPENDIX "A"

Maximum Amounts of Pollutants Permitted in Drinking Water.

(From U.S. Environmental Protection Agency Drinking Water Regulations, June 24, 1977*)

Substance	Maximum Contaminant Level (MCL) in mg/L
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Calcium	200.0
Chromium	0.05
Total coliform bacteria	1/100 mL (membrane filter method)
Detergents	0.5
Iron	0.3
Lead	0.05
Magnesium	150.3
Manganese	0.05
Mercury	0.002
Nitrate Nitrogen	10
pH	5-9
Phenol	0.001
Selenium	0.01
Silver	0.05
Turbidity	Monthly average of 1 turbidity unit, or 5 units provided it does not interfere with water treatment processes
Zinc	0.005

*States may impose limits on substances not included under federal regulations. State standards *must be equal to or more restrictive than* existing federal standards — they cannot be more lenient than the federal standards.

APPENDIX "B"

Recommended Water Test Kits

The Hach Company makes kits of varying sophistication that will test for the chemicals listed below (and many chemicals not listed). These kits are characterized by accuracy, ruggedness, compactness and simplicity.

In general, test apparatus which employ *electronic* methods are most accurate, fastest to use . . . and most expensive. They have batteries which wear out and filters and/or sensitive probes which may become damaged or lost. For this reason, these set-ups are not recommended for use by students in grades 7-10. However, they are ideal for college use and advanced classes in secondary schools.

Several Kit Styles Are Available

Hach kits which employ *color comparator* devices (chemicals are added to the water sample and its color is compared to a "wheel of colors") are ideal for use in grades 7-10 (and even lower). These kits are easy to use and they develop a wealth of essential science skills such as "volumetric conversion," "titration," "interpolation of numerical values" and "adherence to specific directions and time lines." Color comparator kits are fun to operate and tests normally consume enough time so that kids feel they are practicing "real science." Kit components are rugged and large enough so they won't get lost. As with all Hach Test Kits, everything is contained in a sturdy plastic carrying case.

Color cubes are the easiest and fastest to use, and the least expensive of all Hach kits. A fifth grader can operate these kits without difficulty if the directions are simplified. However, cube kits are small and easily lost, and the procedures are so simple students may lose interest if repetitive tests are done. Nevertheless, cube kits are wonderful for filling out your battery of water test equipment at very low cost.

Free Catalog Offer

Hach continually refines its product line so there's real likelihood that my recommendations as to "what is best" may be outdated by the time you read this. See a current Hach catalog for an up-to-date and complete listing of water test kits and accessories. When ordering kits remember *students do break glassware!* Order some "replacement glassware" with each kit you purchase. The **Teacher's Guide to Ordering** (starts on page 33) suggests specific items you may need.

If you are confused, have questions or want a free catalog, call the Hach toll-free number listed below:

HACH **1-800-525-5940**

Ordering Information
starts on next page

TEACHER'S GUIDE TO ORDERING

Hach Test Kits Recommended for Use in Grades 7 through 10

Additional test kit listings and details of a generous quantity discount for multiple test kit and reagent orders are given in Hach's *Products for Analysis* Catalog. If you don't have a current edition, call **1-800-525-5940** toll-free and ask for your free copy (Colorado residents: call 669-3050 collect).

When planning for a large number of students, you'll find it's a good idea to order additional reagents at the same time you place your test kit orders. Not only will you avoid reagent shortages, but you'll be able to take advantage of the quantity discount.

One reagent package you should consider is the "Bulkpac." Available for a variety of "pillowed" reagents, it contains 1000 pillow packets of a single premeasured reagent. Bulkpacs offer a lower price per pillow than smaller sized containers.

Replacement Parts Available

Although most kit parts are made of sturdy plastic and are large enough not to get lost easily, some test procedures require *glass* parts, and a few items are small and "misplaceable." It might be wise to order "extras" when you place your test kit and reagent order.

Most of you should have access to clippers (The clippers used to open Hach pillow-packed reagents are similar to ordinary nail clippers.) and distilled water (sold in most grocery stores). But if you don't, you'll find them listed along with many other needed laboratory items in the *Products for Analysis* catalog.

Teacher's Guide to Ordering

Everything you need for successful testing is contained in Hach Test Kits. The information below tells you how many tests may be performed with each kit and suggests refill reagents and items for which you may want "spares."

Key to 'Test Method' Symbols

CC: Test kit using a color-comparator test system
C: Test kit using a color cube for color comparison
T: Test kit using "drop-count" titration for determining results. (You count the drops needed to make a sample "change color.")

Test	Products for testing	Test Method	Average Number of Tests per Kit or Container	Catalog Number	Comments
ALKALINITY					
	Model AL-AP, Alkalinity Test Kit	T	100	1433-00	
	Refills/Replacements				
	Bromcresol Green-Methyl Red Indicator Pillows		100	943-99	
	Phenolphthalein Indicator Pillows		100	942-99	
	Sulfuric Acid Solution, 0.03*N*				
	118 mL (4 oz)		100	413-37	Dropping bottle
	473 mL (1 pt)		400	413-11	
	Mixing bottle, pkg/6			2327-06	Glass: nice to have spares
	Plastic measuring tube			438-00	Nice to have spares
CARBON DIOXIDE					
	Model CA-23, Carbon Dioxide Test Kit	T	200	1436-01	
	Refills/Replacements				
	Phenolphthalein Indicator Solution				
	15 mL (½ oz)		200	1897-36	Comes in dropping bottle
	473 mL (1 pt)		3200	1897-11	
	Sodium Hydroxide Solution				
	118 mL (4 oz)		200	671-37	Dropping bottle
	473 mL (1 pt)		400	671-11	
	Plastic measuring tube			438-00	Nice to have spares
	Mixing bottle, pkg/6			2327-06	Glass: nice to have spares

(Continued on page 34)

Ordering Information

Test	Products for testing	Test Method	Average Number of Tests per Kit or Container	Catalog Number	Comments
CHLORIDE					
	Model 7-P, Chloride Test Kit	T	100	1440-00	
	Refills/Replacements				
	Chloride Indicator Pillows		100	1043-99	
	Silver Nitrate Solution				
	118 mL (4 oz)		100	397-37	Dropping bottle
	473 mL (1 pt)		400	397-11	
	Plastic measuring tube			438-00	Nice to have spares
	Mixing bottle, pkg/6			2327-06	Glass: nice to have spares
CHLORINE					
	Model CN-66T, Total Chlorine Test Kit	CC	100	2231-03	For measuring chlorine in wastewater, tap water, swimming pools and natural waters suspected of pollution
	Refills/Replacements				
	Total Chlorine Reagent Pillows		100	14076-99	
	Total Chlorine Pillow Bulkpac		1000	14076-28	
	Color viewing tube			1730-00	
	Stopper for viewing tube			1731-00	
	Total Chlorine Test Cube Kit	C	50	20604-00	Same comments as Model CN-66T
	Refills/Replacements				
	Total Chlorine Reagent Pillows		100	14076-99	
	Total Chlorine Pillow Bulkpac		1000	14076-28	
	Cap for test cube			19073-00	Nice to have spares
CHROMIUM (HEXAVALENT)					
	Model CH-8, Hexavalent Chromium Test Kit	CC	100	1834-00	Measures low level chromate such as found in tannery wastes and wastewater. (Range = 0-1.5 mg/L)
	Refills/Replacements				
	Chromium Reagent Pillows		100	12710-99	
	Chromium Reagent Pillow Bulkpac		1000	12710-28	
	Color viewing tube			1730-00	
	Stopper for viewing tube			1731-00	
	Hexavalent Chromium Test Cube Kit	C	50	12527-00	Range = 0-1.0 mg/L
	Refills/Replacements				
	Chromium Reagent Pillows		100	12710-99	
	Chromium Reagent Pillow Bulkpac		1000	12710-28	
	Cap for test cube			19073-00	Nice to have spares
DETERGENTS					
	Model DE-2, Detergents Test Kit	CC	32	1432-03	Extraction with chloroform; **not** recommended for use below Grade 9
	Refills/Replacements				
	Detergents Test Solution				
	118 mL (4 oz)		32	1059-37	Dropping bottle
	473 mL (1 pt)		128	1059-11	
	Chloroform, 473 mL (1 pt)		32	14458-11	
	3.78 L (1 gal)		250	14458-17	
	Color viewing tube, marked			1736-00	Glass: nice to have spares
	Stopper for viewing tube, pkg/6			14480-01	Nice to have spares
	Safety goggles (not included in kit)			20972-00	Recommended

(Continued on page 35)

Test	Products for testing	Test Method	Average Number of Tests per Kit or Container	Catalog Number	Comments
HARDNESS					
	Model 5-EP, Compact Hardness Test Kit	T	100	1454-00	
	Refills/Replacements				
	Titrant Reagent, 118 mL (4 oz)		100	426-37	Dropping bottle
	473 mL (1 pt)		200	426-11	
	946 mL (1 qt)		400	426-16	
	Hardness Reagent Pillows		100	962-99	
	Mixing bottle, pkg/6			439-06	Glass: nice to have spares
	Plastic measuring tube			438-00	Nice to have spares
	Model 5-B, Low Cost Hardness Test Kit	T	100	1453-00	Comes in paper-board carton
	Refills/Replacements				
	Titrant Reagent, 118 mL (4 oz)		100	426-37	Dropping bottle
	473 mL (1 pt)		400	426-11	
	946 mL (1 qt)		800	426-16	
	Powdered Hardness Reagent				
	28 g (1 oz)		100	213-20	
	113 g (4 oz)		400	213-14	
	454 g (1 lb)		1600	213-01	
	Measuring spoon, 0.1 g			511-00	Nice to have spares
	Mixing bottle, pkg/6			439-06	Nice to have spares
	Plastic measuring tube			438-00	Nice to have spares
	Model HA-71A, Total Hardness Test Kit	T	100	1452-01	Dual range: 1 drop titrant = 1 mg/L or 1 grain/gal (17 mg/L)
	Refills/Replacements				
	Hardness 1 Buffer Solution				
	118 mL (4 oz)		100	424-37	Dropping bottle
	473 mL (1 pt)		400	424-11	
	Hardness 2 Solution (ManVer® 2 Indicator)				
	118 mL (4 oz)		100	425-37	Dropping bottle
	473 mL (1 pt)		400	425-11	
	Hardness 3 Solution				
	118 mL (4 oz)		100	426-37	Dropping bottle
	473 mL (1 pt)		400	426-11	
	Erlenmeyer flask, 125 mL			505-43	Glass: nice to have spares
	Plastic measuring tube			438-00	Nice to have spares
NITRATES/NITRITES					
	Model NI-12, Nitrate-Nitrite Test Kit	CC	100	14081-00	Range: 0-0.5 mg/L as *nitrite*-nitrogen and 0-100 mg/L as *nitrate*-nitrogen
	Refills/Replacements				
	Nitrate Reagent Pillows (NitraVer® 5)		100	14035-99	
	Nitrite Reagent Pillows (NitriVer® 3)		100	14078-99	
	Color viewing tube			1730-00	Glass: nice to have spares
	Stoppers for viewing tube, pkg of 12			2118-02	Nice to have spares
	Model NI-14, Low Range Nitrate Test Kit	CC	50	14161-00	Dual range: 0-1 and 0-10 mg/L. May also be used to determine nitrite
	Refills/Replacements				
	Nitrate Reagent Pillows (NitraVer 6)		100	14120-99	
	Nitrite Reagent Pillows (NitriVer 3)		100	14078-99	
	Color viewing tube			1730-00	Glass: nice to have spares
	Stoppers for viewing tube, pkg/12			2118-02	Nice to have spares

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(Continued on page 36)

Test	Products for testing	Test Method	Average Number of Tests per Kit or Container	Catalog Number	Comments
NITRATES/NITRITES (continued)					
	Nitrate Test Cube Kit	C	50	14037-00	High range — 0-50 mg/L
	Refills/Replacements				
	Nitrate Reagent Pillows (NitraVer 5)		100	14035-99	
	Cap for test cube			19073-00	Nice to have spares
	Nitrite Test Cube Kit	C	50	20596-00	Low range — 0-1 mg/L
	Refills/Replacements				
	Nitrite Reagent Pillows (NitriVer 3)		100	14078-99	
	Cap for test cube			19073-00	Nice to have spares
AMMONIA-NITROGEN					
	Model NI-8, Ammonia-Nitrogen Test Kit	CC	100	2241-00	
	Refills/Replacements				
	Nessler Reagent, 118 mL (4 oz)		100	151-37	Dropping bottle
	473 mL (1 pt)		400	151-11	
	Color viewing tube			1926-00	Glass: nice to have spares
	Stopper for viewing tube			1731-00	Nice to have spares
DISSOLVED OXYGEN					
	Model OX-2P, Dissolved Oxygen Test Kit	T	100	1469-00	
	Refills/Replacements				
	Dissolved Oxygen 1 Reagent Pillows		100	981-99	
	Dissolved Oxygen 2 Reagent Pillows		100	982-99	
	Dissolved Oxygen 3 Reagent Pillows		100	987-99	
	PAO Titrant, 118 mL (4 oz)		100	1079-37	Dropping bottle
	473 mL (1 pt)		400	1079-11	
	Dissolved Oxygen Bottle w/glass stopper			1909-02	Glass: nice to have spares
	Glass stopper (only) for DO bottle above			1909-01	Nice to have spares
	Plastic measuring tube			438-00	Nice to have spares
pH					
	Model 17-N, Wide Range pH Test Kit	CC	100	1470-11	Measures pH from 4 to 10
	Refills/Replacements				
	Wide Range pH Indicator Solution				
	118 mL (4 oz)		100	216-37	Dropping bottle
	946 mL (1 qt)		800	216-16	
	Color viewing tube			1926-00	Glass: nice to have spares
	Stopper for viewing tube			1731-00	Nice to have spares
	pH Test Cube Kit	C	100	12519-00	Range: 6.5-8.5, only
	Refills/Replacements				
	Phenol Red Indicator Solution				
	15 mL (½ oz)		100	211-36	Dropping bottle
	59 mL (2 oz)		400	211-26	Dropping bottle
	118 mL (4 oz)		800	211-37	Dropping bottle
	Cap for test cube			19073-00	Nice to have spares

(Continued on page 37)

Test	Products for testing	Test Method	Average Number of Tests per Kit or Container	Catalog Number	Comments
PHOSPHATE					
	Model PO-19, Orthophosphate Test Kit	CC	100	2248-00	Dual range: 0-5 and 0-50 mg/L phosphate
	Refills/Replacements				
	Phosphate Reagent Pillows		100	2209-99	
	Phosphate Reagent Pillow Bulkpac		1000	2209-28	
	Color viewing tube			1730-00	Glass: nice to have spares
	Stopper for viewing tube			1731-00	Nice to have spares
	Dropper, marked for measuring			14197-00	Glass: nice to have spares
	Phosphate Test Cube Kit	C	50	12522-00	Range: 0-5 mg/L phosphate
	Refills/Replacements				
	Phosphate Reagent Pillows		100	2209-99	
	Phosphate Reagent Pillow Bulkpac		1000	2209-28	
	Cap for test cube			19073-00	Nice to have spares

MULTI-TEST KIT

(The one to buy if you will be doing several tests and prefer to have all testing reagents and apparatus in one compact carrying case)

Test	Products for testing	Test Method	Average Number of Tests per Kit or Container	Catalog Number	Comments
	Model AL-36B, Water Ecology Test Kit	T and CC	100 tests of each	1802-02	Measures Acidity, Alkalinity Carbon Dioxide, Dissolved Oxygen, Hardness and pH
	Refills/Replacements				
	Alkalinity: Order same replacements as for Alkalinity Test Kit, Model AL-AP				
	Carbon Dioxide: Order same replacements as for Carbon Dioxide Test Kit, Model CA-23				
	Dissolved Oxygen: Order same replacements as for Dissolved Oxygen Test Kit, Model OX-2P				
	Hardness: Order same replacements as for Hardness Test Kit, Model HA-71A				
	pH: Order same replacements as for Wide Range pH Test Kit, Model 17-N				

TURBIDITY AND COLIFORM TESTING — *See page 38*

HACH HELP-LINE

1-800-525-5940

Your toll-free number for quick ordering service and more information

(Continued on page 38)

Ordering Information

TURBIDITY AND COLIFORM TESTING (With membrane filter apparatus)

Use the Gelman membrane filtration apparatus* to determine turbidity and numbers of coliform bacteria. Membrane filter equipment is easy and fun to operate and it teaches a variety of "scientific techniques." Tests are relatively time consuming (5 to 10 minutes per test) to perform and so keep student occupied. Membrane filtration apparatus is fairly expensive but the filter funnels are very rugged and durable.

For Both Tests You Will Need —	**Cat. No.**
Magnetic filter holder (rugged plastic)	13529-00
Filter flask, 250 mL size, glass	546-46
Hand-operated vacuum pump. Comes with tubing	14283-00

For Coliform Testing, You Also Will Need —	
Membrane filters with pads. Filters are gridded for easy counting. Sterile. 100 (10 pkg of 10)	21269-00
or	
Pads (without filters) with dispenser, 1000 (10 pkg of 100)	14918-00
Filters, gridded, pkg/200	13530-01
Forceps (tweezers)	14537-00

Coliform Testing (continued)	**Cat. No.**
Alcohol burner, 60-mL size	20877-60
or	
Bunsen burner (burns on propane)	21627-00
M-Endo broth ampules, 20/pkg	21273-00
Sterile plastic petri plates, 500/pkg (It's o.k. to reuse these but don't heat sterilize them — they melt!)	14852-00
Sterile pipet, plastic, 1 mL. 200/pkg	21233-01

For Turbidity Testing, You Also Will Need —	
Membrane filters without grids, 100/pkg	13530-00
or	
Membrane filters with grids, 200/pkg	13530-01

*If you have other brands of membrane filtration apparatus on hand, any one of them should be suitable for these tests.

OPTIONAL COLIFORM TEST† (Does not require filtration equipment)

Sterile plastic petri plates, 500/pkg (It's o.k. to reuse these but don't heat sterilize them — they melt!)	14852-00
Sterile pipets, plastic, 1 mL. 200/pkg	21233-01
EMB (Eosin Methylene Blue) Agar,† 114 g (¼ lb) (enough for about 1000 tests)	21777-14

†For class work, boiling the medium (you make it up with water; full directions are on the bottle) will remove most microbes and *all* coliform bacteria. Therefore, if you don't have a pressure cooker or autoclave handy, boiling may be used instead of true sterilization — and results will not be too far "off."

HACH EDUCATION 'PACKAGE'

Student Reading Unit, *Water, Water Everywhere, But . . ..*	21975-00
Reference Unit, *Water Quality Factors*	21974-00
Teacher's Unit (Questions and Exams with Answers, Experiments, Report Writing Directions and Notes for the Teacher)	21976-00

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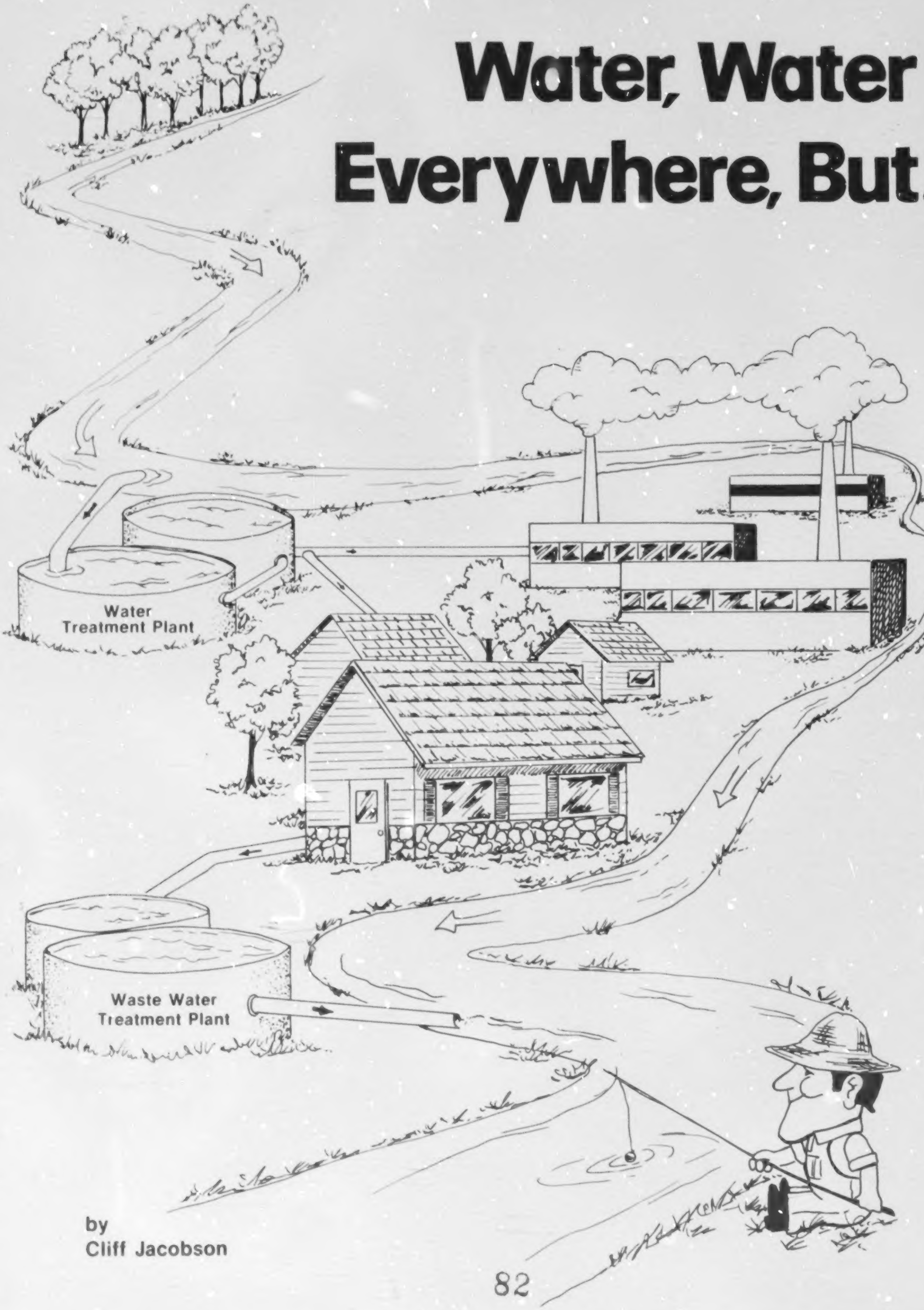
Water
Treatment Plant
Waste Water
Treatment Plant

by
Cliff Jacobson

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HACH

Student
Reading
Unit

First Edition

WATER, WATER EVERYWHERE, BUT . . . .

By Cliff Jacobson

Teacher of Environmental Science
Hastings Junior High School
Hastings, Minnesota

Technical Editing by

Josephine W. Boyd

Senior Technical Editor
Hach Company
Loveland, Colorado

Hach Company
Loveland, Colorado 80539

WATER, WATER EVERYWHERE, BUT . . . .

A Manual about Water Pollution

By Cliff Jacobson
Technical Editing by Josephine W. Boyd

About the Author

This text has been prepared by Cliff Jacobson, Environmental Science Teacher, Hastings Junior High School, Hastings, Minnesota. Mr. Jacobson holds a B.S. degree in forestry from Purdue University and an M.S. degree in secondary education from Indiana University.

In addition to his junior high teaching duties, Mr. Jacobson serves as an instructor for the Minnesota Department of Natural Resources Outdoor Education Program. He has published numerous articles and books about the environment, camping and backpacking and has served as a professional canoe guide.

About the Editor

Scientific editing duties were performed by Dr. Josephine W. Boyd, Senior Technical Editor for Hach Company. Dr. Boyd holds a B. Chemical Engineering degree and a B. Business Administration degree from the University of Minnesota. Her M.S. and Ph.D. degrees are from the same institution in the fields of microbiology and biochemistry.

Dr. Boyd has worked on various biological and chemical problems of water supply and wastewater disposal in arctic areas of the North American and European continents as well as in municipal systems in temperate areas. She is a member of a number of professional societies and has extensive experience as a writer for both popular and scientific publications.

Student
Reading
Unit

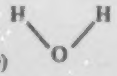
WATER, WATER EVERYWHERE, BUT . . . .

It may be dreadfully silent or boastfully loud. It is strong enough to move huge mountains and carve great valleys, to turn heavy wheels and run powerful engines. Without it there would be no factories or jet planes, no computers or video games, no plants, animals, fish, insects . . . or people.

It is water, and all life on planet earth depends on it!

As chemical formulas go, water is pretty simple stuff — just two parts hydrogen and one part oxygen, bound together in a spherical shape. The two hydrogen atoms are hardly more than bulges on the surface of the much larger oxygen atom. There isn't much to get excited about until you realize the tiny atoms of hydrogen and oxygen making up water are so firmly stuck together that few things in nature, short of electrical storms, can break them apart.

Water is very simple stuff — just two atoms of Hydrogen (H) and one atom of Oxygen (0).



(H_2O)

That's a good thing, too, for four-fifths of our planet's surface is water, and we'd be in real trouble if, on a whim, those hydrogen and oxygen atoms decided to go their separate ways. Imagine what it would be like if our rivers and lakes were here today, gone tomorrow.

In scientific language, water is a very **stable compound** — one we seem to have an endless supply of. Right? Hardly. Check out the pie graph below.

Stable things don't break down easily. A **compound** is a substance that's made up of two or more elements.

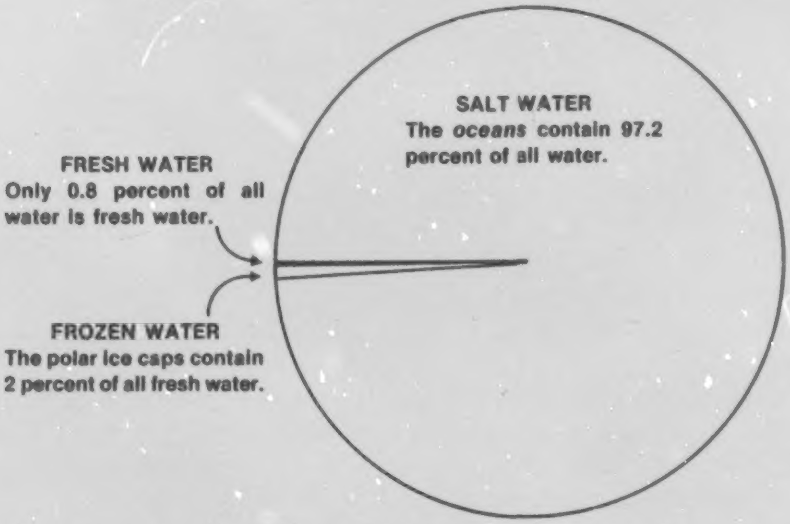


FIGURE 1 Graphs showing how the earth's water is distributed

Ninety-seven and two-tenths (97.2) percent of all the water on earth is salty ocean water. It must be **desalinized** before we can use it. Desalinization is expensive, and pumping salt-free ocean water thousands of miles across a country the size of America is even more expensive. For now, at least, removing salt from sea water isn't very practical.

Desalinized means that the salt has been removed. "Saline" means salty.

Arctic pack ice and **icebergs** are not the same thing. **Arctic pack ice** forms in the salt water of oceans but it doesn't contain salt. When these large masses of ice freeze, the salt crystallizes out.

Icebergs also are found in the ocean. They, too, are made up of fresh water, but are formed when huge chunks of ice from *fresh water glaciers* break off and are carried out to sea.

Humidity is moisture in the air. It is another name for the gaseous form of water.

There are 1,000 million in a **billion** (1,000,000,000).

Technology is scientific "know-how."

An **aquifer** is an underground reservoir.

Two percent of our water is frozen solid in the form of **arctic pack ice** and **icebergs.** Getting fresh water from this ice would mean breaking off a chunk and towing it to a warm climate where it could melt. Don't laugh. The idea was considered (and abandoned) when California experienced serious droughts in the late 1970s!

Only eight-tenths (0.8) of one percent of all the water on earth is immediately available for people to use. The rest is salt water or ice or in the atmosphere as **humidity** and clouds. What's worse, the fresh water available is not evenly distributed. Huge areas of our planet are desert and have almost no water at all.

Three-fourths of the earth's population lack clean fresh water. **Billions** of people drink and bathe in polluted water, and there is no sign things are getting better very fast. Though we do have the **technology** to make all the world's polluted water safe for drinking, we don't have the money. Poor countries just can't afford to clean all their dirty water.

Most Americans aren't very interested in water quality. After all, most of our water is pretty good stuff. Even the largest American cities — Chicago, Detroit, Los Angeles, Cleveland, New York — have clean, clear water. And most of our lakes and rivers have good populations of fish and are safe enough for boating, even for swimming.

But all that is beginning to change. We've gone from a population of around 76,000,000 Americans in 1900 to more than 235,000,000 in 1983. That's a 309 percent increase in just 83 years! Accordingly, the demand for clean water has skyrocketed, too.

We Americans are "water rich" and we've let it go to our heads. For example, our five great lakes contain more fresh water than almost any area of similar size in the world.* Together, they hold one-fifth of all the earth's lake and river water. Fully one-third of our Nation lies over underground **aquifers** which could supply a single well with billions of gallons of water a day! In fact, we've got at least 20 times *more water* under the first half mile of ground than the amount of water stored in all our rivers, lakes and streams.

That's pretty impressive, huh? Maybe it's too impressive. We use tremendous amounts of water without a second thought. It takes 150,000 gallons to grow a ton of corn, 7,000 gallons to produce a steer for market, and about 13 gallons to make a single pound of steel.

If we consider agricultural and industrial uses, every man, woman and child in America uses . . . and pollutes about 1000 gallons of water a day — about three times as much as the average European!† In many parts of the country there is no reserve of fresh water. When droughts come, as they did on the East Coast and West Coast of the United States in the mid 1970s, we just grin and bear it and try to import water from some area of the nation that has it.

Over-use and pollution of water will be our major problem in the next century. There's not a drop of doubt about that!

---

*Lake Baikal in the Soviet Union is an exception. This lake is so deep it contains as much fresh water as all our five great lakes put together!

†It has been estimated that by the year 2000, America will use one-half trillion (500,000,000,000) gallons of water a day. If, by that date, the population of this country reaches 300,000,000 as expected, every man, woman and child will need almost 1,500 gallons of water a day!

The Search for Fresh Water

During the past few decades the earth has suffered a number of severe droughts. The ones in America mentioned earlier were mild compared to those in Asia and Africa.

Obviously, we can't change the whims of Mother Nature. But we can prepare for the unexpected by practicing sensible conservation methods. As you'll discover, it's not always in our best interest to dam huge bodies of water or divert rivers to obtain the water we need.

A case in point: Every spring when the snows melt in the Soviet Union, the Kremlin is reminded of a quirk of nature which has robbed Mother Russia of much of the fresh water she needs. Many of Russia's great rivers flow north to the Arctic Ocean rather than south to nourish the ever-thirsty regions of central Asia. In short, the Soviet Union does not have enough fresh water — a major reason for this nation's repeated crop failures and its desire to buy as much grain as possible from the United States.

As early as 1830, a surveyor named Alexander Shrenk suggested the problem be solved by diverting the Pechora River (which flows north) into the Volga (Russia's most important river). No one took him seriously, probably because Soviet engineers weren't up to the task of completing such a massive project "in those days." *Today they are,* and they fully intend to change the direction of at least a dozen north-bound rivers — a feat that would be the grandest engineering project of all time and one which might cause some of the worst environmental problems in history!

Towns and seaports would be destroyed and thousands of fish would die — their breeding places wiped out forever. Equally frightening is the thought that the Arctic Ocean might get too salty if it's not continually replenished by fresh water. The extra salt would lower its freezing point and possibly cause the polar ice cap to melt. The result might be a warming trend which could change the climate of the continent! There also is concern that the changed winds and currents in the area might reduce rainfall in the very locations targeted to benefit from the proposed project.

Irrigation: Whenever you draw water from a river (for whatever reason) you reduce its flow. If enough people **irrigate** their land with water from the same river, the river may run dry. Hundreds of rivers in the western United States start powerfully at their **headwaters** only to become bare trickles at their **mouths.** What happens then to the life of the river, to the breeding grounds of the fish and wildlife and to the people who depend on the river for their livelihood? Granted, water is recycled, but not nearly as fast as it's used.

People **irrigate** their land when they supply it with water.

The place where a river runs into another waterway is called the **mouth.** The **headwaters** of a river is the place it starts.

Disturbing new evidence suggests that we may be "mining" our deep underground **aquifers** in some of the western states. Recent scientific studies indicate it takes hundreds or thousands of years for these giant aquifers to fill with water. And farmers and ranchers are using this water much faster than nature can replace it. Each year, the irrigation pumps go deeper and deeper to reach needed water. In some areas it is already too expensive to drill deeper. Getting fresh water may mean searching for alternative sources.

An **aquifer** is a deep underground reservoir filled with water.

Irrigating deserts and dry regions is possible *only if we have an unlimited supply of fresh water!*

The Water Cycle

Water is a "renewable resource." This means you can use it over and over again. By comparison, oil *is not* renewable — at least in our lifetime. Burn it up and it's gone. You can't make more of it!

The water cycle is simple enough, at least in theory. Precipitation in the form of rain and snow falls from the clouds and filters through the soil. When the rain/snow water reaches a **nonporous** layer of rock (called the "bedrock") it follows the slope of the rock and eventually finds its way to streams, rivers, lakes and oceans. This "ground water," as it is called, moves so slowly its speed can barely be measured. Although most large cities rely on river and lake water to supply their water needs, almost one-third of the people in the United States relies on ground water. Getting enough of it usually is quite simple: Just drill a hole into the ground (sink a well) until you hit water!

A **porous** substance has holes; a **nonporous** one doesn't.

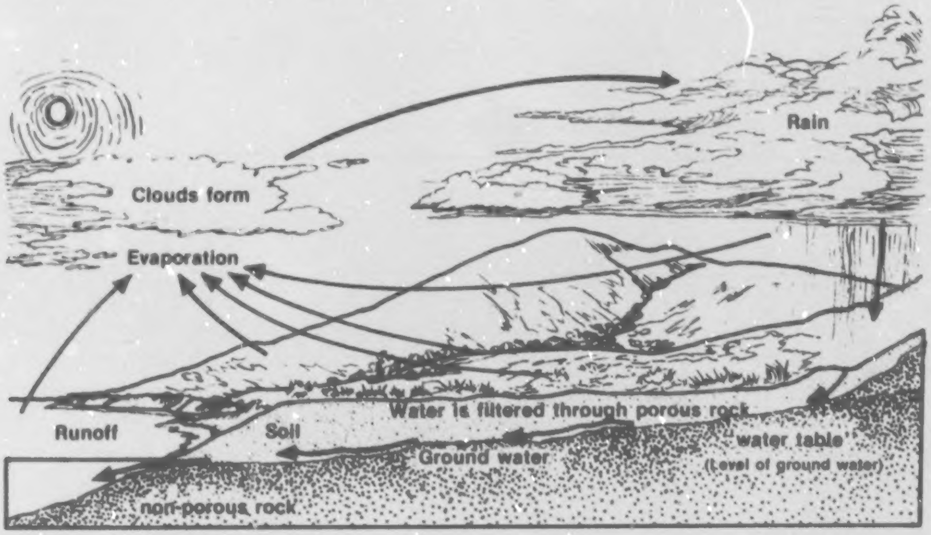


FIGURE 2 The water cycle

As the ground water flows over rocks and through soil particles it picks up minerals, many of which are essential for life. Water by itself has no taste (ever drink distilled water? Yuk!). But as it absorbs small amounts of minerals such as iron, sulfur, magnesium and fluoride, it gains taste and character. However, too many minerals make water "hard"* and reduce its ability to clean clothes and dishes. You may have a water softener in your home to remove these minerals.

"Soft water" may be great for washing dishes, but it's not very good for drinking. In fact, very soft water may increase your chances of getting a heart attack.

When ground water reaches the earth's surface, some of it evaporates as pure water. Any minerals it contained are left behind. This is nature's way of cleansing the water of foreign materials. Evaporation purifies even the most polluted water.

Question: Does salty ocean water evaporate as fresh (not salty) water or salt water? Answer: as *fresh* water, of course!

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*The main villains are calcium and magnesium.

The moral of the story is there are only two places in the water cycle where water is purified:* 1. *when it evaporates from rivers, lakes, and oceans,* and 2. *when it is filtered in the ground.* If you contaminate the air or ground, you contaminate the water!

A lot of our shallow ground water has been **contaminated** by waste materials poured onto the ground by city and industrial workers and by individuals. (Did you ever pour gasoline, paint or weed killer on the ground? If so, you *may* have **polluted** your own ground water!) Perhaps you've heard of "Love Canal." In the 1950s, when people didn't have all the information they have now, employees of a company near Niagara Falls, N.Y., began dumping quantities of very poisonous chemicals into a company-owned landfill. As the years passed, the chemicals found their way into the drinking water supply of area residents. Chemical analysis revealed the water contained 82 chemical compounds, including 11 known or suspected **carcinogens.** The problem reached crisis proportions in the late 1970s when many people became sick and pregnant women lost their babies. Millions of dollars worth of law suits were filed by angry residents of the area and, in the end, the company responsible had to pay — both for the medical damage which resulted and for resettling the people in new homes.

If you **contaminate** something, you pollute it.

Pollution means "too much." A *little bit* of these materials probably won't hurt anything. But if everybody in your block does it, watch out!

Carcinogens are things that cause cancer.

It would have been far cheaper to dispose of the company wastes properly than to pay the medical and clean-up costs. Lack of knowledge and a certain amount of carelessness caused this terrible mistake.

As mentioned before, ground water moves very slowly — often only a few dozen feet a year. So if ground water becomes contaminated, it may be nearly impossible to clean. Removing poisonous wastes may be possible only through the natural process of evaporation (when the water eventually reaches the earth's surface). In the meantime, it may take years before a contaminated well is safe to use again. The water in the Love Canal area may require a lifetime, or even much longer, to purify!

Did you ever wonder why streams keep flowing all summer long even when it hasn't rained for weeks? You guessed it — ground water. As you can see, ground water is pretty important stuff. If you pollute it, you also may pollute the streams, rivers and oceans into which it flows!

Water which flows underground accounts for about two-thirds of all the fresh water in the world. Can you see why we're so concerned when wastes are buried near a water supply?

Industries alone are not to blame for water pollution. In fact, some of the worst pollution disasters have been the result of unconcerned city officials and citizens. Some **sanitary landfills** aren't very sanitary. Every time it rains, water seeps into the ground and washes over the buried wastes, ultimately polluting the ground water.

Sanitary landfill: a dump that doesn't pollute the environment. These dumps are *supposed* to be located in an area where they won't create air and water pollution. Each day, wastes are covered with soil so they won't smell.

Virtually every city dump has strict regulations about what can and can't be disposed of. Generally, these rules prohibit dumping *pesticides, paints, surgical hospital wastes, bulk detergents and poisonous chemicals.* But people often don't follow the rules. They know their chances of "getting caught cheating" are slim.

A very real problem is the lack of government-approved sites for the dumping

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*Oxygen helps remove *some* types of pollution from lakes and rivers.

of poisonous wastes. Government agencies, notably the EPA (Environmental Protection Agency), does careful studies to determine what areas of the country have specific soil conditions which can tolerate and contain poisonous wastes. Only a few places in a few states are safe dump sites for **hazardous** wastes. But when these sites are proposed, people who live in the areas selected oppose them. After all, no one wants to live near a poisonous waste facility. As a result, few hazardous dumps are approved. And we're all the real losers. For without safe places to put poisonous wastes, many companies are forced to continue to do what they've done for years — dump them in unsafe places! Problems like "Love Canal" will continue to develop until we take the responsibility for building proper disposal sites for poisonous materials.

Hazardous wastes are those that are risky or dangerous to be around.

Right now, nearly 200,000 landfills and unauthorized dumps are being operated in the United States. This doesn't include all the abandoned sites in the country. According to **EPA** studies, some 85 percent of existing landfills originally were designed to be **reclamation** projects to fill marsh lands and old gravel pits. Most of these old landfills had no clay-like linings to keep wastes from seeping into the ground water. The result has been a real problem!

The **EPA** is the Environmental Protection Agency.

Reclamation means to put the land back the way it was before people started using it carelessly. Most reclamation projects don't do a very good job of "reclaiming" the land.

• YOU CAN'T CLEAN WATER BY FILTERING IT THROUGH POLLUTED SOIL!

• DEVELOPING *SAFE* CHEMICAL DUMP SITES IS ONE OF THE MOST IMPORTANT THINGS WE CAN DO TO IMPROVE WATER QUALITY!

Acid Rain

You've seen how water can be polluted by poisonous wastes and sewage. It also can be contaminated as it falls to the ground in the form of rain or snow. Here's how.

When factories and home owners burn coal or oil and automobiles burn gasoline, they produce large amounts of sulfur and nitrogen oxide gasses. These gasses enter the air from smoke stacks, chimneys and auto exhausts. Then they mix with rain and form a sour acid cocktail called ACID RAIN. Acid rain may kill plants and fish, dissolve auto finishes and house paints, and reduce ancient stone sculptures to unrecognizeable blobs of rock.

This serious problem has become a matter of international concern. Some of the historic buildings in Venice (Italy) are crumbling because of acid gasses and acid rain.

Seventy percent of the lakes in Norway and 80 percent of those in the Adirondack Mountains of New York have no fish because the waters are too acidic. And recent studies show that as many as one-fourth of the lakes in Minnesota's famed Boundary Waters Canoe Area are affected by some degree of acidity. But, because the forest soils around these lakes are naturally acid, we need more knowledge before we can say smoke stacks, chimneys and cars are the source of *all* the acid found in lakes.

Whatever the source, fish and the food fish eat cannot survive in a highly acid environment!

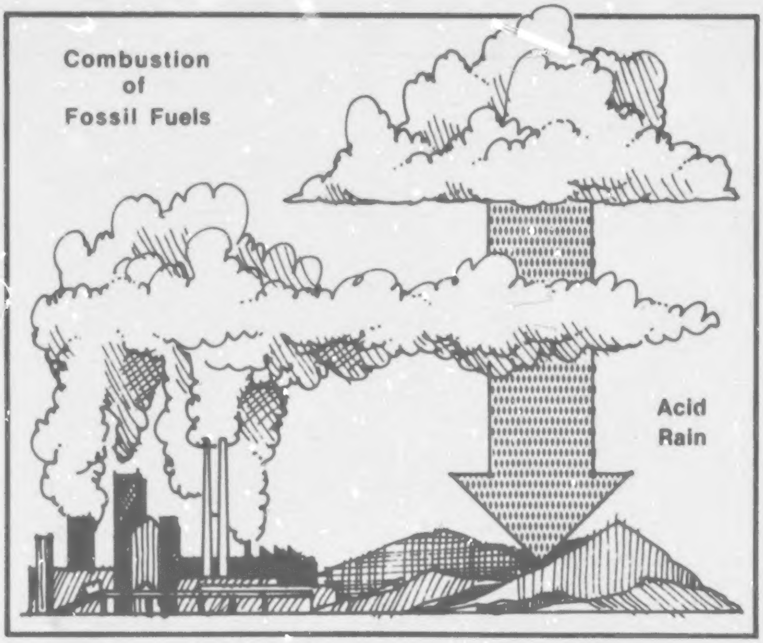
Combustion
of
Fossil Fuels
Acid
Rain

FIGURE 3 How acid rain forms*

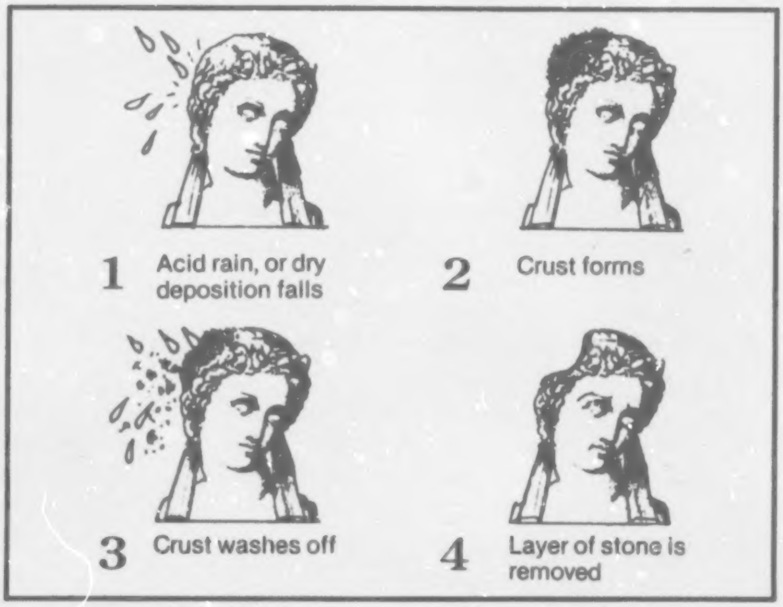
1 Acid rain, or dry deposition falls
2 Crust forms
3 Crust washes off
4 Layer of stone is removed

FIGURE 4 How acid rain may reduce stone sculptures to blobs*

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*Figures 3, 4, 6 and 7 are taken from *Acid Rain*, a publication of the U.S. EPA (EPA-600/9-79-036. July, 1980)

Before you can understand the nature of acid rain, you'll have to learn about pH.* pH is a measure of how acid or basic (alkaline) a solution is. The pH scale looks like this:

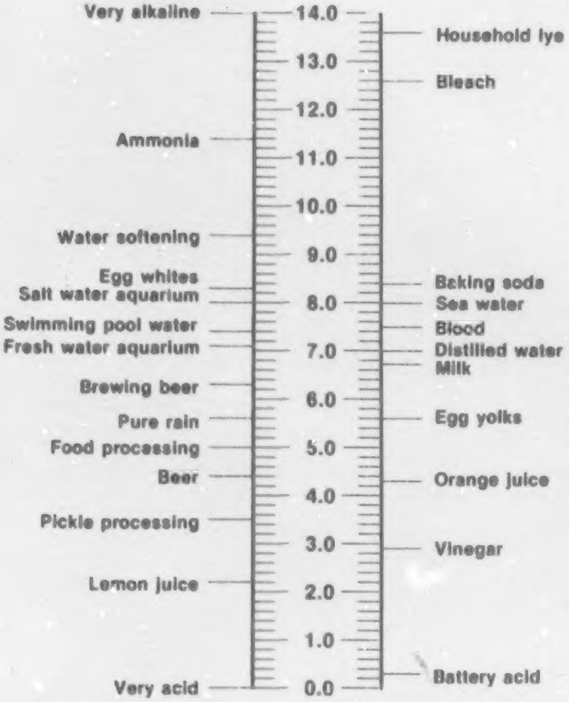

FIGURE 5 pH scale showing the pH of some common substances

Alkaline and **basic** mean the same thing.

A pH of 7 is neutral. Zero is the most acid end of the pH scale and 14 is most basic. The important thing to know is that a one-unit change on the pH scale, say from 3 to 4, equals a *10 times* change in the strength of the acid or base.

Thus, a pH of 3 is *10 times* more acid than pH 4, *100 times* more acid than pH 5, and *1,000 times* more acid than pH 6! At the other end of the scale, a pH of 14 is *10 times* more **basic (alkaline)** than pH 13, *100 times* more basic than 12, and *1,000 times* more basic than 11.

If you put your hand in a solution of near zero pH for a minute or two, the acid will burn your skin and make cuts and hangnails sting. But dip your hand in a pH 2 solution and you'd feel something about as sour as lemon juice. However, if you put your hand in an alkaline solution near pH 14, it will be much harder on your skin — partly because alkaline solutions are harder to rinse off and partly because alkali is harder on human skin.

A ONE-UNIT CHANGE IN pH EQUALS A 10 TIMES CHANGE IN THE STRENGTH OF THE ACID OR BASE!

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*See the discussion of pH in the **Water Quality Factors** pamphlet.

Pure rain has a pH of around 5.6 (slightly acid). But the average rain and snowfall in most states east of the Mississippi River runs between 4 and 5, with some individual storms going as low as 3.0! That's real cause for concern.

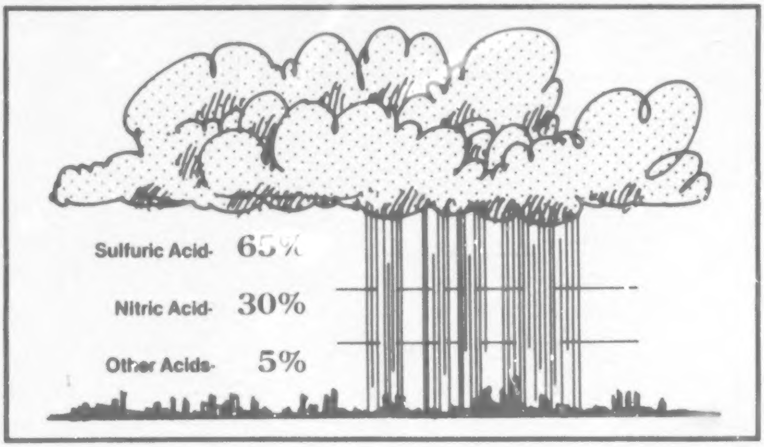
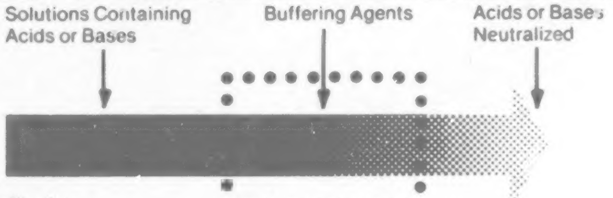


FIGURE 6 Typical acid rain components found in the northeastern United States*

Falling rain and snow function as an air cleaner by pulling any particles suspended in the atmosphere to the ground. When there's a long time period between rains, sulfur and nitrogen oxides produced by cars and industries accumulate in large **stagnant** air masses. When rains finally come, they mix with these chemical oxides and form *nitric* and *sulfuric* acids. The "acid rains" which result lower the pH of the waterways into which they fall — sometimes to quite low levels.

Stagnant means stationary. Stagnant things don't move.


Solutions Containing Acids or Bases
Buffering Agents
Acids or Bases Neutralized

Buffering

A substance has *buffering* capabilities when, coming into contact with a solution that contains acids or bases, it neutralizes the acids or bases without appreciably changing its own nature.

Normal rainwater (pH 5.6) is not highly buffered and therefore is susceptible to pH decreases.

Airborne alkaline particles sometimes buffer air pollutants. Soils, on the other hand, can have an enormous buffering capacity.

FIGURE 7 How "buffering" agents work*

Acid rains frequently are "buffered" (see Figure 7) by **alkaline** particles in the air or by soils rich in these Alka-Seltzer® like ingredients. If a lake has poor buffering capacity *and* is located in the path of polluted winds, the effects of acid rain will be doubly bad!

Alkaline and **basic** mean the same thing.

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*See footnote on page 7 for reference.

Acid Rain — What Can Be Done?

For years, industrialists thought they had solved the acid rain problem by simply raising the heights of their smokestacks. The idea was to get the pollutants high enough so winds would blow them away from nearby towns. Some smokestacks reached impressive heights. A nickel smelting plant in Sudbury, Ontario has a chimney rising nearly one-quarter mile into the sky!

But blowing pollutants "away" is not the answer — for what goes up, comes down . . . somewhere. Acid rain no longer falls on Sudbury. Instead, it drops on villages and cities as far away as Maine!

There are ways to stop acid rain dead in its tracks, and you're already familiar with some of them. One answer is to install antipollution devices in our factories and automobiles. But these devices are expensive and, as always, costs must be passed on to the consumer. This means higher prices for everything we buy or lower wages for workers who manufacture these products. People must decide if they want to spend money for cleaner water and air and better health for everyone.

Effective air pollution control equipment in our industries and cars can help solve the acid rain problem. Proper treatment of sewage and industrial wastes *before* they are dumped and providing *safe places* to dump them will eliminate a lot of ground water contamination. Farmers can help by using fertilizers and pesticides carefully.

Providing clean water for America will cost money . . . and we will all have to pay!

The Damming of America

Many people think of rivers as . . .

- Places to get rid of excess water when it rains.
- Sources of water to irrigate farm lands.
- Devices to power electric generators.
- Sewers to carry away the wastes of a city.
- Ribbons of highway to float barges.

Few people are really interested in, or understand, the **ecology** of rivers.

Ecology is a household word, though not everyone understands its meaning. Ecology can be defined best as the *study of the relationships between living organisms and their environment.*

We have built dams along virtually all of our major rivers to aid in flood control, to supply water for irrigation, to make water levels suitable for boating and to provide lakes for recreation in places where lakes don't naturally exist. But when you construct a dam along a river, you change the **ecology** of the area. Let's consider the Columbia River as an example.

Ecology is the study of the relationships between living things and their environment. The person who studies these relationships is called an **ecologist.**

The Columbia begins in western Canada, flows south and west through Washington and Oregon and finally ends in the Pacific Ocean after a journey of some 1,200 miles. The Columbia is a giant among rivers. With all its tributaries, it drains a region of nearly 260,000 square miles!

At one time, the Columbia ran wild and free for its entire length. Now there are at least 135 major dams along this river and its tributaries. Only 50 miles of the Columbia remain dam-free.

So many dams on the Columbia have resulted in no real current. One slack water area blends with another and the cold glacial waters of the river become sun-baked pools which no longer support trout and other desirable fish. Trout are cold water fish; they need temperatures of 42 to 54 degrees Fahrenheit (5.6 to 12.2 degrees Celsius) to survive.

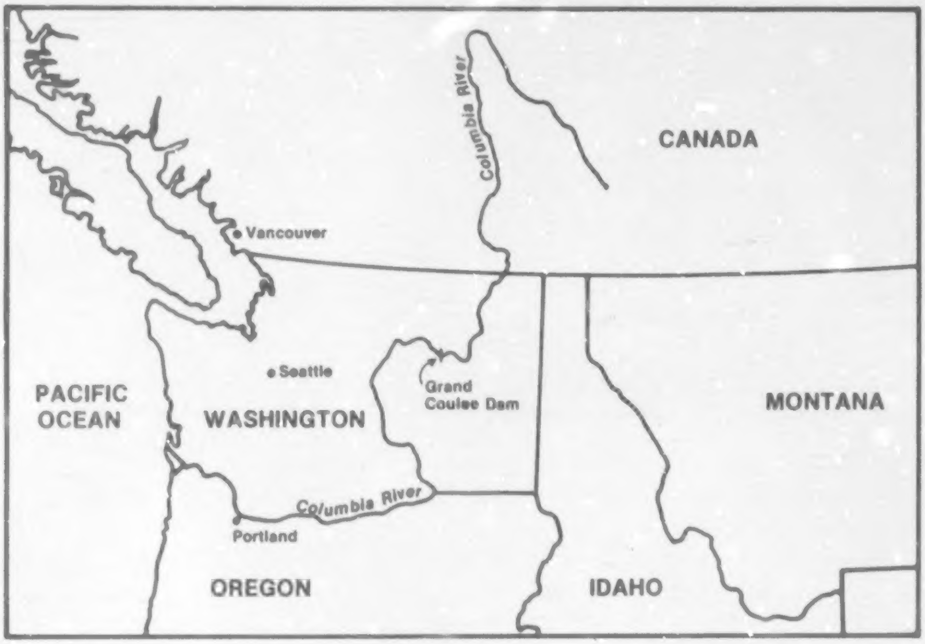


FIGURE 8 Map of the Columbia River basin

As the sun beats down upon the **impounded** waters, it warms them. Bacteria levels and disease increase. Parasites grow rapidly and attack the fish. Soon, huge numbers of fish become sick and die. Then the "rough" fish (carp and suckers) move in. Trout? Forget it. They can't live here anymore.

Impounded waters are confined within a reservoir.

The changing water levels that dams produce create other serious problems for fish. Some simple organisms begin to breed when water levels rise or fall. They get the "wrong signals" when water in the reservoir goes up or down as the dam is opened and closed. You can imagine the problems that result!

As water levels change, currents, water depth and the amount of oxygen in the water also change. This affects fish and the tiny organisms they feed upon.

You're probably familiar with the "fish ladders" constructed along many western dams. These "ladders" are supposed to allow **anadramous** fish to climb up over the dams when they swim from the ocean back upstream to their fresh water breeding areas. But fish ladders don't work very well. Many fish don't survive the climb. There is no known way to get fish safely over a 700-foot high dam!

Anadramous fish spend part of their life in salt water and part of their life in fresh water. Salmon are anadramous fish.

When **anadramous** fish run upstream, birds and animals living in and along the river enjoy a marvelous feast. Eagles, ospreys, herons, bears, mink and otters all get a hearty meal. Because the fish runs are in spring when the young of most animals and birds are born, they help ensure the survival of thousands of newborn creatures.

But the dams have changed all that. Only the strongest anadramous fish make it upstream beyond the dams to breed. Two things are being done to compensate for this loss of fish. First, government officials maintain active fish-stocking programs on many rivers. Without the stocking programs, there would be far fewer fish in the rivers and less wildlife along the banks. The second way people hope to increase the numbers of anadramous fish is with a new type of ranch called a "fish ranch." Located on free, undammed streams, these ranches are stocked with salmon eggs rather than cattle or horses. Young fish hatch at the ranch and swim out to sea. When they return "home" to breed two years later, wildlife and humans have great fishing.

Ecologically sensitive: Areas which can be hurt by even small changes in the environment.

By now you've probably developed a healthy dislike for dams. But not all dams are bad. Those constructed *too high* may be bad, those built in **ecologically sensitive** areas may be bad, and *too many* dams on one river may be bad.

Some dams *do* improve water quality, *do* reduce flooding and *do* provide convenient recreation areas for millions of people. A thoughtfully designed dam actually may improve conditions for wildlife by restoring water to areas previously drained by man.

Moderation means to "temper" or restrain your actions — not to go overboard or to excess.

Aquatic organisms live in water.

The key to a trouble-free environment is **moderation!** I'll bet you know about at least one dam near your home that was built years ago and is no longer serviceable. Dams like these have no useful purpose. They merely provide an obstacle to fish and **aquatic** organisms, harm the ecology of the river and may break, causing a disastrous flood.

There are thousands of idle dams in America. Even working dams often are in sad need of repair. That's something to think about before we construct more new dams!

Pollution of Our Waters

Irrigators use sprinklers or ditches to supply water to farm land in areas without enough rain. Excess irrigation water runs off the fields and into streams and rivers.

Minimal means the least amount possible.

If cities, factories and farm **irrigators** carefully cleaned every drop of water before releasing it into the environment, water pollution wouldn't be such a serious concern. Mostly, it's a matter of simple economics. People would rather spend their money on cars and television sets than build a modern sewage treatment plant. Industries and farmers would rather not pay for pollution control equipment. Consequently, wastewater rarely is cleaner than the **minimal** cleanliness required by law.

Microorganisms are living things so small you need a microscope to see them. Bacteria are a type of microorganism.

There's an old saying that if you dump sewage into a river, the river will clean itself in 90 miles. But that's not true anymore. It never was true if a lot of sewage was dumped into the water. Two centuries ago, river towns were spaced *much more* than 90 miles apart. There was plenty of distance (and time) between towns for **microorganisms** in the water to decompose sewage and convert it to nonpolluting substances.

Now, communities are located back to back, one behind the other. If each city dumps its sewage, the load on the river increases fast. Ultimately, the pollution becomes too great and the river gets sick. What's worse, rivers die when microorganisms can't possibly digest all the waste materials that are dumped into them — stuff like mercury, chromium and pesticides. In fact, around 1,000 new substances enter the water each year. Some definitely are harmful.

We simply don't have the time, money or manpower to research the potential effects of all the substances in our water, let alone keep track of who's dumping them. Methods of treating our water and caring for planet earth that were good enough for Grandpa a century ago simply aren't good enough today!

Pollution . . . What Is It?

What do you know about "pollution?" Here are two situations, A and B. In one or both situations, we're polluting. Can you guess which one and why?

A: It's 1776, just after the signing of the Declaration of Independence. You live in a small community along the Hudson River. You keep your garbage in a huge wooden barrel and once a month you dump it into the river. Are you polluting the river?

B: Consider the same situation in 1983. Are you polluting?

Answers: A — no, B — yes!

The **variable** here is *the amount* of waste, *not* the kind of waste. Certainly, your 1983 wastes would include plastic, aluminum and glass products that living things can't decompose. Your 1776 wastes would consist of meat scraps, pieces of hides and such — food for microorganisms. But the issue is still *the amount* of waste, not the type. If everyone in 1776 dumped their garbage into the Hudson River (and everyone probably did!), it would cause no problems. There just weren't many people in those days so very little garbage was thrown in the river. It's quite possible that the river *did* clean itself in 90 miles!

A **variable** is a factor which can change or affect the outcome of an experiment.

Today, things are different. If everyone living along the Hudson dumped garbage into it, they would not only pollute the river beyond recognition, they'd fill it up. There would be no water. People would be able to walk across the garbage! Throwing garbage into waterways is no laughing matter.

Biodegradable — A Big Word with a Hang-up

Nothing lasts forever. Even aluminum cans and glass bottles eventually break down biologically, chemically or mechanically. Or, they may **degrade** from interaction of all three processes.

Degrade means to "break down."

Biodegradable is a word you hear a lot. It means "can be broken down by the action of living things." The living things, mostly bacteria and fungi, feed upon the waste materials and reduce them to simple chemicals which can be used over and over again by plants and animals. Orange peels, apple cores and leaves — anything which once was living — is biodegradable. Some man-made molecules (like certain brands of detergents) also are eaten by living things and are, therefore, biodegradable.

Chemically degradable: Iron rusts or "oxidizes." This is a chemical process; no living thing is involved.

On a broader scale, plant-like organisms called **lichens** chemically dissolve rocks and convert them to soil. It may take lichens 500 years or more to produce an inch of topsoil — a reason why soil conservation practices are so important.

Lichens are made up of two kinds of organisms — green algae and fungi.

Mechanically degradable: Water *wears* away rock. What is now a high rock falls will one day be reduced to a rapid. Eventually, the rapid will be worn away.

Hydrologists are scientists who study water.

In the late 1960s, **hydrologists** shut off the American Niagara Falls to repair the high rock lip eroding away. They reinforced the lip so the falls would stay the same height and continue to attract tourists.

You'll note that these processes — biodegradable, chemically degradable, mechanically degradable — only tell you *how* the product breaks down, *not how long it takes*. It's quite possible for some biodegradable materials to degrade faster *mechanically* than *biologically*. For example, if the climate is too cold for bacteria to grow (and temperatures below freezing are too cold!), a common substance like an apple core might require months or years to **decompose.** In fact, wind and snow may *wear* the apple away long before it is consumed by bacteria and fungi.

Decompose means the product can be broken down by microorganisms. Decomposition is a *biological* process because living things are involved. Rot and decay are types of *biological decomposition*.

Did you ever wonder how long it takes for some modern materials to break down? If you threw out a "tin" can, the steel in the can would be rusted completely in 100 years. An aluminum can would take much longer to **degrade** — maybe 500 years! A plastic bag would remain in the environment for about 2,000 years, while pieces of glass from a bottle might be around one million years from today!

Degrade means "to break down."

The important lesson is that pollution means "too much." And *too much of anything*, biodegradable or not, is bad for the environment. Solving pollution problems is never as simple as it seems.

Types of Water Pollution

We'll examine the effects of six kinds of water pollutants, including:

— Biodegradable wastes
— Plant nutrients
— Heat (thermal pollution)
— Sediments
— Poisonous and nonpoisonous chemicals
— Radioactive wastes

Biodegradable Wastes

Biodegradable means: "can be broken down into harmless chemicals by living organisms."

Bacteria and fungi eat **biodegradable** wastes and convert them into harmless chemicals. Food scraps and human excrement are examples of this kind of waste. Some synthetic chemicals (like some detergents) are biodegradable.

Biodegradable products can harm the environment because they provide food for bacteria. This affects water quality in two ways:

1. When **aerobic** bacteria eat garbage they multiply and consume large amounts of oxygen needed for fish and **aquatic** animals. As oxygen levels drop, "good" fish leave and "rough" fish like carp and suckers move in. If oxygen levels get too low, almost everything — even the aerobic bacteria — dies! All that's left are **anaerobic** bacteria. And anaerobic bacteria are inefficient garbage disposers that make stinky smelling gasses while they work. (Have you ever smelled rotten eggs near a sewer? That smell was made by anaerobic bacteria.)

Aerobic bacteria use oxygen from the air. They are the best workers for decomposing wastes.

Aquatic creatures live in water.

Anaerobic bacteria can live without oxygen from the air.

2. Not all bacteria are beneficial and necessary for decomposing biodegradable wastes. Some bacteria are **pathogenic,** or capable of causing disease. Figure 9 summarizes how biodegradable wastes affect the water environment.

Pathogens may get into water from sewage dumped by cities, from animals and birds, or from man.

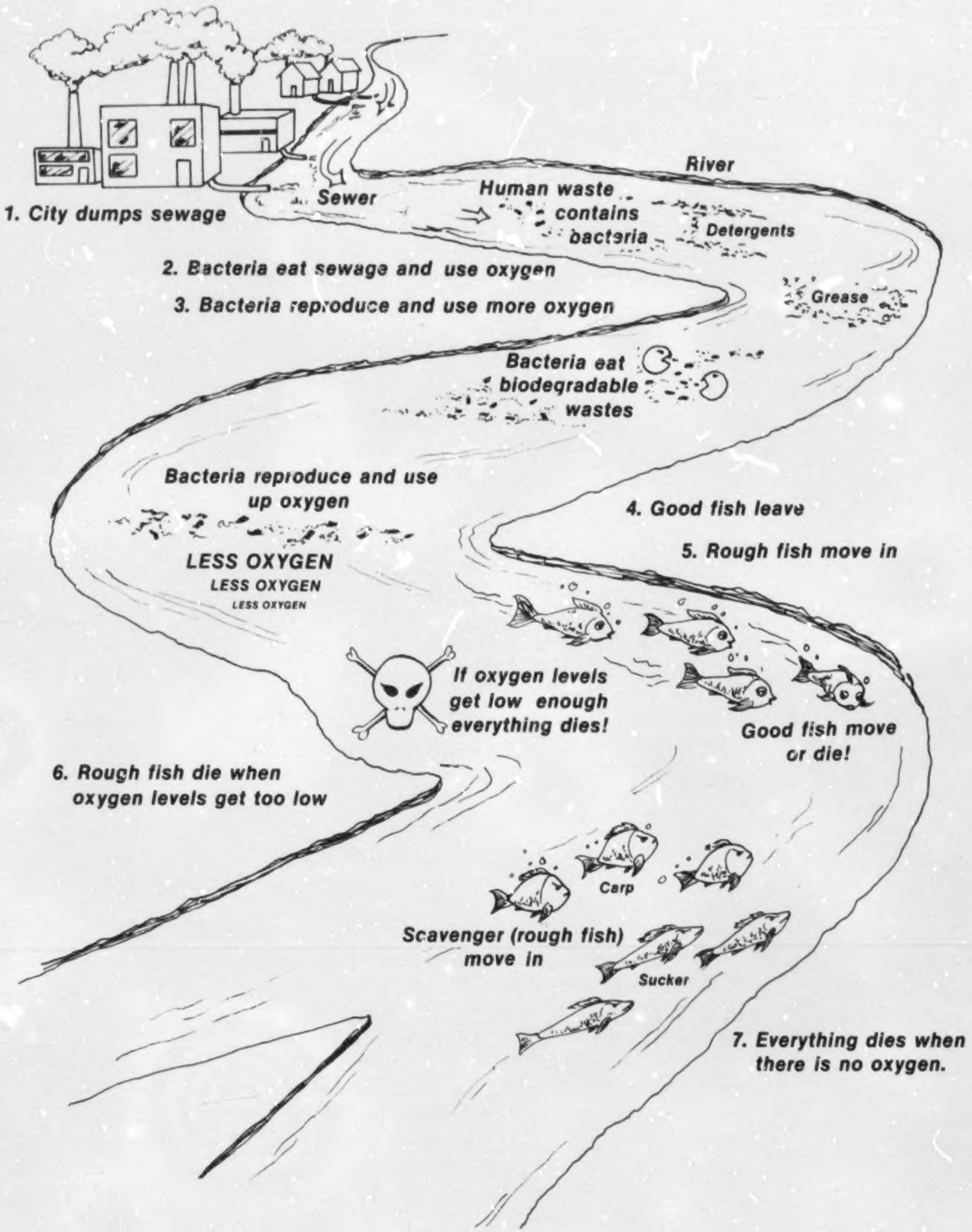

1. City dumps sewage
Sewer
River
Human waste contains bacteria
Detergents
2. Bacteria eat sewage and use oxygen
3. Bacteria reproduce and use more oxygen
Grease
Bacteria eat biodegradable wastes
Bacteria reproduce and use up oxygen
LESS OXYGEN
LESS OXYGEN
LESS OXYGEN
4. Good fish leave
5. Rough fish move in
If oxygen levels get low enough everything dies!
Good fish move or die!
6. Rough fish die when oxygen levels get too low
Carp
Scavenger (rough fish) move in
Sucker
7. Everything dies when there is no oxygen.

FIGURE 9 How biodegradable wastes affect the water environment

An **effluent** is a liquid that flows out of some place. (**Treated effluent** is another name for treated sewage or other waste.) An **influent** flows in! Water which flows from your faucet is an **influent.** That which goes down the drain is an **effluent.**

Some of the same biodegradable wastes (notably human excrement) which support beneficial bacteria also support pathogenic forms. High levels of bacteria may mean epidemics of diseases like typhoid, cholera and dysentary which are carried by water. The answer to this is: *Don't* allow cities and towns to dump untreated **effluent** directly into a river or lake!

Viruses are the smallest and most unusual of "living things." Viruses don't have cells like other organisms. Some viruses are rod-shaped; others look like golf balls. Still others — like the ones that attack bacteria — look like tadpoles. Viruses must have living cells in order to reproduce themselves.

Sewage treatment plants add chlorine to treated effluent to kill the harmful bacteria which transmit these diseases. However, chlorine generally does not kill **viruses** like the ones that cause hepatitis and polio. The answer? Use a virus-killing disinfectant like ozone. Ozone's biggest disadvantage is that it is a lot more expensive than chlorine.

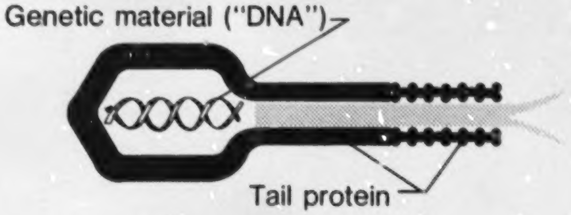


FIGURE 10 Drawing of a "bacteriophage" — a virus able to attack bacteria

Plant Nutrients

Every spring, farmers fertilize farm soil with products rich in nitrogen, phosphorus, potassium and other nutrients. These fertilizers may be commercial types or organic manures. In either case, the effects are the same: The plants get the chemicals they need to grow properly.

When rains come, some of the fertilizers are washed into nearby waterways. Water plants absorb the nutrients and, like the farmers' crops, grow wildly. As sunlight and water temperature increase during mid-summer, growing conditions become just right for algae and they form "blooms" in stagnant water areas.

"Dog days" occur from early July until early September when the dogstar, Serius, is in the sky.

Because algae bloom during **"dog days,"** sometimes that term is used to describe this algae bloom phenomenon, though the scientific word "eutrophication" (YOU-tro-feh-kay-shun) — which means "enrichment with nutrients" — is more accurate.

In a sense, eutrophication is an aging process. As nutrient levels increase, the amount of algae and other plants growing in the lake also increases. Eventually, the lake fills in, the area dries up and a swamp forms. In time, even the swamp disappears and a forest begins to grow. Nature requires hundreds or thousands of years to convert a lake to a forest by the process of eutrophication. But we can speed the aging process by simply enriching the lake with fertilizers (plant nutrients) or human wastes.

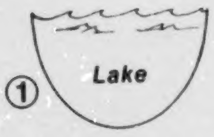
This is the major reason why many states are adopting legislation prohibiting building homes right next to rivers and lakes. If a house is too close to a waterway, toilet wastes and ground-up garbage may seep into the water and . . .

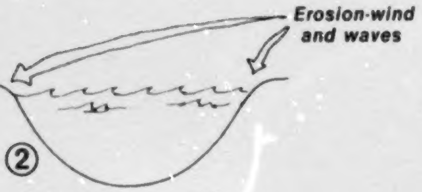
1. Increase plant growth and cause eutrophication.
2. Increase bacteria levels which will reduce the amount of oxygen.
3. Permit the existence of **pathogens.**

Pathogens are bacteria, fungi (molds), viruses and protozoa (microscopic animals) that cause disease.

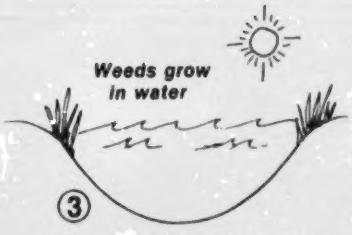
The process of "natural eutrophication" is summarized in Figure 11.

Natural
EUTROPHICATION

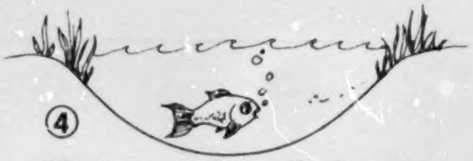



Erosion-wind and waves
②

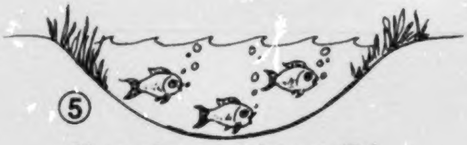
Lake edges erode


Weeds grow in water
③

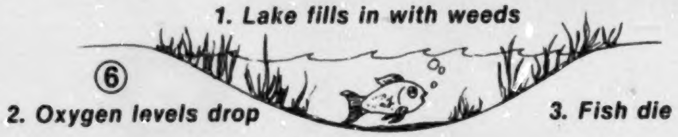
Sunlight penetrates shallow areas.

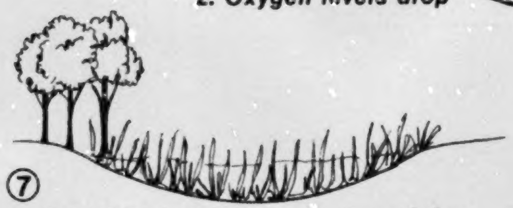


Weeds support growth of worms, insects, and protozoa.

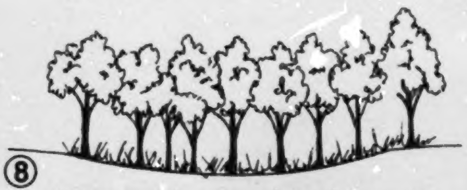


More algae...and more fish


1. Lake fills in with weeds
⑥
2. Oxygen levels drop
3. Fish die



Lake becomes swampy - trees take root along edges



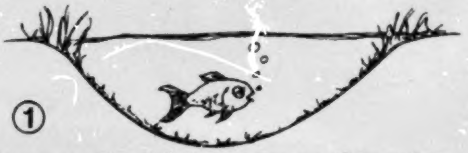
Swamp dries up - forest appears

Man Made
EUTROPHICATION

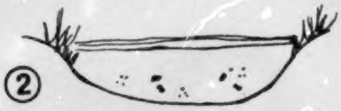
The natural process of eutrophication ordinarily takes hundreds or thousands of years. But we can speed up the process "artificially" by adding biodegradable wastes to the water.

The biodegradable wastes:

1. Make algae grow. 2. Increase bacteria levels. 3. Remove oxygen from the water.



Algae grow and form scum on the water



Bacteria increase and use oxygen, algae also use oxygen

Algae make oxygen by the process of photosynthesis in the presence of sunlight. They also make carbon-rich foods. At night, algae "burn" these foods for energy—a process called "respiration." Plants (including algae) consume oxygen and release carbon dioxide when they respire.

FIGURE 11 Natural and man-made eutrophication

Heat (Thermal Pollution)

An important physical relationship exists between the amount of dissolved oxygen in a body of water and its temperature. Simply put, "the warmer the water, the *less* dissolved oxygen, and vice versa." Figure 12 shows the relationship.

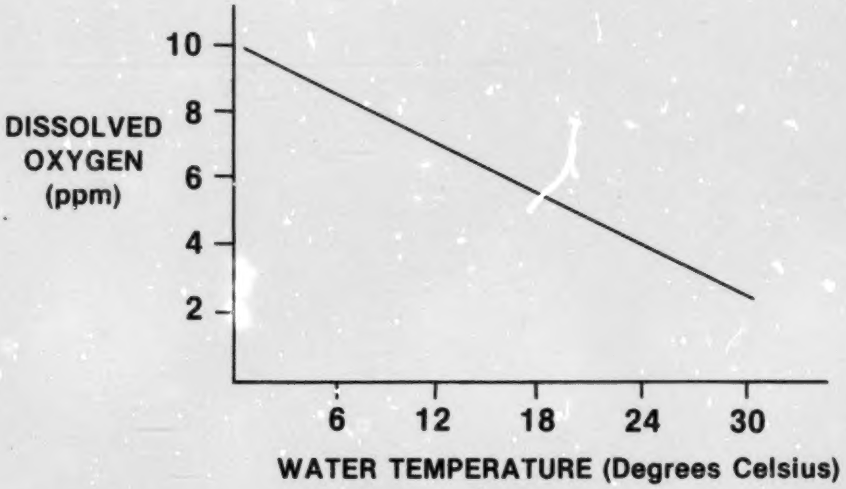


FIGURE 12 Chart showing decrease in dissolved oxygen as water temperature increases

For this reason, heat or "thermal pollution" is a very real problem, especially in shallow ponds which get very warm in mid-summer. Most fish simply can't stand warm water and/or low levels of dissolved oxygen. A notable exception is the lungfish (Figure 13) in Florida.

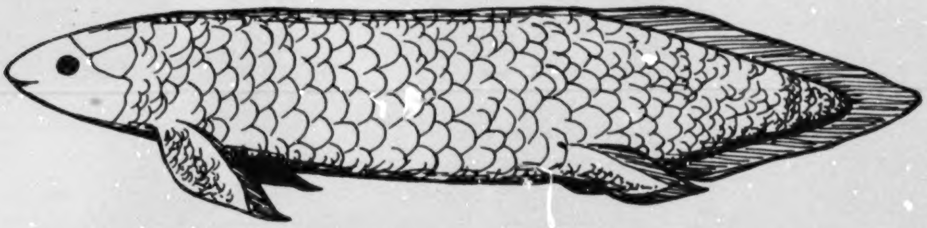


FIGURE 13 The lungfish. This unusual fish has primitive lungs (air sacks) which allow it to breathe the air like a mammal. Lungfish can even crawl on stumpy fins from one pond to another.

Thermal pollution also may result when industries — especially electrical power companies — dump the water used for cooling their machines into waterways. Water temperatures even miles from the dump sites may rise dramatically.

The result may be dead fish, fish eggs that won't hatch or a total change in the fish population as warm water varieties replace the original trout or other cold water fish.

Most states take thermal pollution seriously and have passed laws requiring power plants and industries to cool the water before it is returned to the lake or river. In Minnesota, the law states "the water's temperature 1,000 feet downstream from the discharge point cannot exceed 86 degrees Fahrenheit in summer or 37 degrees Fahrenheit in winter."

It's probably unrealistic at this time to expect industries to meet standards much more rigid than this, though, admittedly, 86-degree water is much too warm for most "good" fish to tolerate. As you might guess, the warm waters near power plants attract lots of "rough" fish.

Sediments (Silt)

Silt is made up of very small particles of rock or soil. It may remain **suspended** in water or settle out. When silt sinks to the bottom of a waterway, it is called *sediment*.

Siltation is the process whereby **silt** is deposited.

Silt gets into waterways when soils erode after a heavy rain. Large amounts of this material may bury fish and shellfish spawning areas and/or cloud the water. Silt limits the penetration of sunlight in water and thereby reduces photosynthesis by algae. Fish can't live in **turbid** water.

Turbid means "cloudy." Turbid waters have a lot of **suspended** particles in them.

Siltation in streams is one of our greatest water pollution problems. Its major cause is soil erosion resulting from poor logging practices (such as clear-cutting large areas), poor farming practices and strip mining. In fact, historians believe the decline of many ancient civilizations may have been due to bad conservation practices which allowed soils to enter streams, irrigation canals and drinking water reservoirs.

The geology and vegetation of a **watershed** also affects the siltation process. If the watershed is rocky with little plant life, top soil will wash into the waterway with every rain . . . and flooding may result! On the other hand, if the watershed has lots of firmly rooted vegetation, it will act as a sponge to trap water and soil and thereby eliminate most erosion and flooding.

The banks and drainage area of a river are its **watershed.**

If you build a shopping center, airport, or major highway near a lake or river, you'll change the drainage pattern of its watershed. Water no longer will be absorbed into the ground after a heavy rain. Instead, it will flow over the cement highway or airstrip into nearby lakes and rivers and possibly cause serious erosion and flooding.

By law, some industrial rivers, like the Mississippi, are **dredged** on a daily basis. Huge cranes scoop accumulated sediment from the river's bottom and deposit it along the banks. The idea is to maintain a deep enough channel (usually nine feet) so that barges can go up and down the river without running aground. Dredging increases siltation and is a never-ending process. Moreover, dredging removes the submerged rocks and logs where fish and small aquatic animals live.

Dredging is the process whereby huge cranes remove sediments from the bottom of a river.

Dredging probably is a necessary evil on industrial rivers, but it is not an environmentally good practice.

Poisonous Wastes

In 1952, the Chisso Chemical Company of Japan began dumping mercury (a waste product of Chisso's fertilizer and carbide manufacturing process) into Minamata Bay in the Shiranui Sea. The mercury was eaten by microscopic plants and animals which, in turn, were eaten by fish. Because the Japanese people eat much more fish than most Americans, large numbers of people were poisoned by the end of the decade from eating mercury contaminated fish from Minamata Bay.

When scientists identified Chisso as the source of the mercury pollution, a long legal battle resulted. In 1973, Chisso was found guilty of poisoning the waters of Minamata Bay and was ordered to pay retribution to the victims of the disaster. To date, the company has paid out claims of more than 80 million dollars!*

Mercury is a heavy metal. You'd think it would sink to the bottom of the ocean and stay there forever without hurting anything. But it doesn't. One reason it doesn't is because much of the discarded mercury isn't pure like the shiny "liquid" you see in thermometers. Instead, it is in a more **soluble** form — one which can be taken up by fish and the people who eat them. Even worse, certain kinds of **microorganisms** in water convert mercury into highly poisonous "methyl" forms, also taken up by fish. When people eat fish containing the various forms of mercury, the mercury stays in their bodies for a long time. The term for this is **bio-accumulation.** Poisons that bio-accumulate are not expelled or broken down naturally in your body. Instead, each dose builds upon the last (accumulates) until levels are reached where illness and death result.

A **soluble** substance is one that dissolves easily.

Microorganisms are living things which are too small to be seen without microscopes.

Bio-accumulation is the process whereby poisons buildup in the systems of living things.

Predator fish, like swordfish, are particularly sensitive to bio-accumulation because they are near the top of the food chain. Figure 14 illustrates the relationships when mercury bio-accumulates.

Mercury isn't the only poisonous waste which bio-accumulates. Pesticides like DDT (banned almost everywhere), endrin and chlordane (available at most hardware stores) also bio-accumulate.

PCBs (polychlorinated biphenyls) are another poisonous compound which bio-accumulates. PCBs are a type of liquid used in electrical fixtures, transformers and hydraulic fluids. They are extremely poisonous even in very small amounts. Millions of pounds of PCBs have been disposed of in landfills, along roads and in lakes and rivers because people didn't know better and for lack of a better place to put them.

PCBs are extremely persistent, which means they don't break down easily. Once you get PCBs in a water supply or in the ground, you're stuck with them for years!

Lead is another dangerous metal tending to accumulate in the tissues of man and animals. Most people think lead poisoning results from inhaling the exhaust of cars which burn leaded gasoline, or from eating paint which contains lead. (A lot of old toys were made of lead and painted with lead paints. When babies chewed on these toys they got lead poisoning!)

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*This information is from the book *Minamata*, by W. Eugene Smith and Aileen M. Smith (Hold, Rinehart, and Winston, Co. New York, 1975). This sensitively written book portrays the horrors endured by the thousands of Japanese who were poisoned by deadly mercury. *Minamata* should be read by everyone who cares about the future of planet earth.

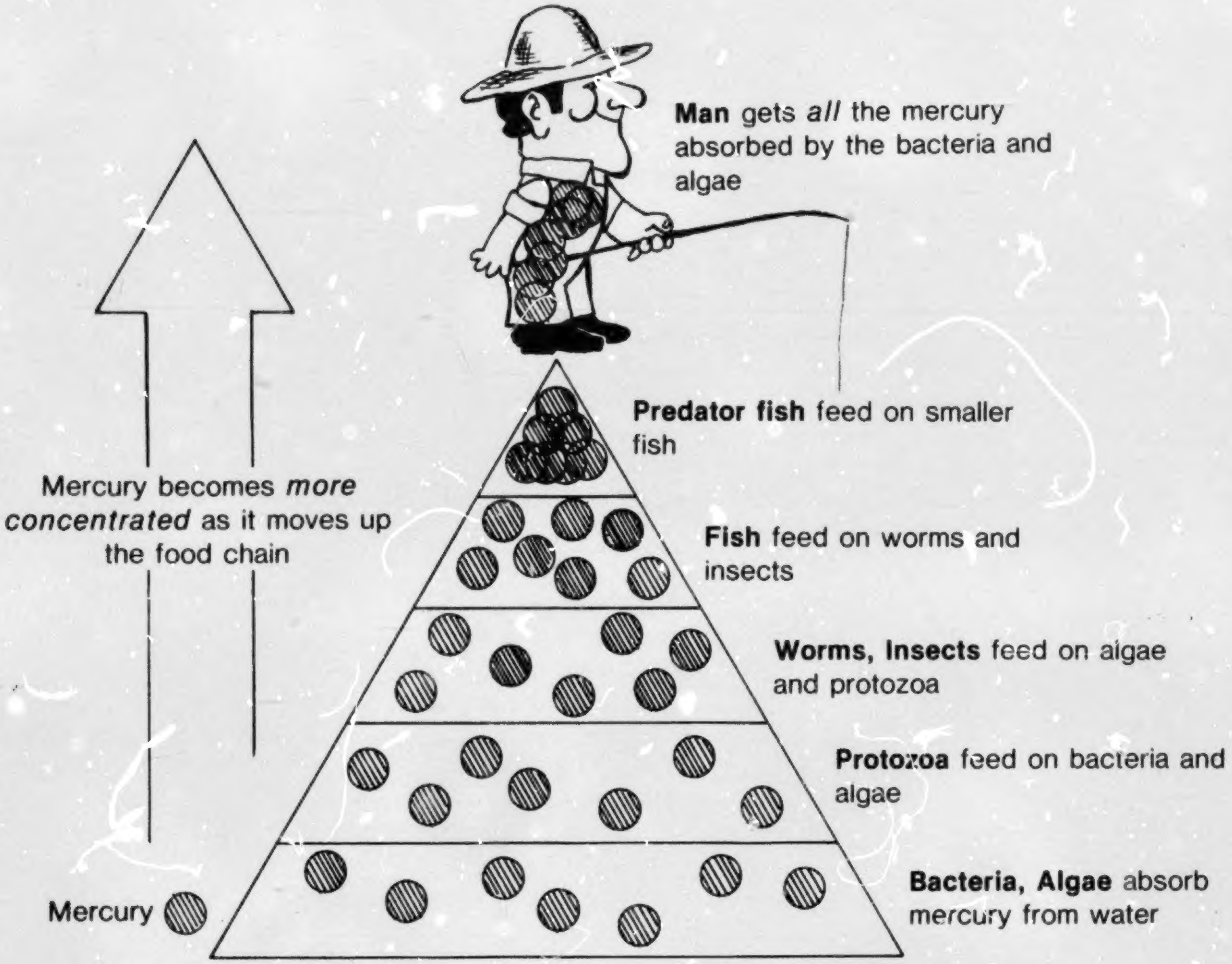

Man gets *all* the mercury absorbed by the bacteria and algae
Predator fish feed on smaller fish
Mercury becomes *more concentrated* as it moves up the food chain
Fish feed on worms and insects
Worms, Insects feed on algae and protozoa
Protozoa feed on bacteria and algae
Mercury
Bacteria, Algae absorb mercury from water

FIGURE 14 How mercury *bio-accumulates*

Most lead enters water supplies through rain, the fallout of lead dust and dumped industrial wastes containing lead. Many paints and insecticides still contain lead, and older homes often have lead-soldered pipes.

Even low levels of lead cause brain damage. In fact, recent studies show many children once thought to be retarded actually are suffering the effects of lead poisoning. When these children are removed from the source of the lead poisoning, they frequently get better.

Fortunately, calcium is a partial **antidote** for lead poisoning. Hard water contains lots of calcium and so does milk!

There are thousands of poisonous chemicals in our waters. Some *bio-accumulate* and some don't. A few, like PCBs and DDT, are very **persistent.** Others, like chlorine — a popular **disinfectant** — are poisonous in large amounts. Treated drinking water contains less than one part chlorine per million parts water. At this low level, chlorine is **beneficial.**

An **antidote** is a medicine that counteracts the effects of a poison.

If something is **persistent** it doesn't go away. "Mosquitoes are persistent."

A **disinfectant** is a chemical that kills bacteria.

A **beneficial** substance is one which helps you or gives you benefits.

Radioactive Materials

When residents of a small Colorado town discovered their drinking water supply was contaminated with radioactive **plutonium,** they became very concerned and ordered a full investigation. They learned that operators of a nearby uranium mine had been releasing radioactive **effluent** into a local creek running into the reservoir. The radioactivity of their drinking water exceeded federal standards by almost 100 percent!

Plutonium is one of the most dangerous and persistent radioactive materials known. It may survive in the environment for more than 500,000 years!

An **effluent** is a liquid that flows *out* of some place. Wastewater that is released by a company or a sewage plant is an effluent.

To make matters worse, a scientist told them the chlorine they added to the water to kill bacteria made the plutonium at least 1,000 times more dangerous! Needless to say, no time or expense was spared in cleaning up the reservoir.

Radiation may be *natural* or *man-made*. Natural radiation comes from two sources: cosmic rays which originate far out in space, and radioactive **isotopes** which are found naturally in water and mineral deposits.

An **isotope** is a different form of an element. (This is a grossly over-simplified definition!)

A large amount of man-made radiation comes from uranium mining operations, nuclear weapons testing fall-out and radioactive wastes released accidentally. Research laboratories and hospitals are some other sources of man-made radiation.

In general, producers of radioactive materials are very careful about how and where they discharge radioactive wastes. Government regulations are very stiff and penalties for violating them are severe. The favored method for disposing of radioactive wastes has been to dilute them with water until they are no longer dangerous. However, some radioactive materials are so persistent in the environment that dilution alone may not guarantee safety.

Radiation accumulates in your body, like some of the poisonous materials mentioned earlier. The smaller you are, the more dangerous is a given dose of radiation. Infants, children and unborn babies are most sensitive to the effects of radiation. High levels of radiation may cause cancerous tumors, deformed body parts . . . and death.

We have yet to develop inexpensive and foolproof ways to get rid of our radioactive wastes!

Sewage Treatment

Contrary to popular belief, cities and farms, not factories, are the major polluters of America's waters. Most of the wastes are biodegradable and come from:

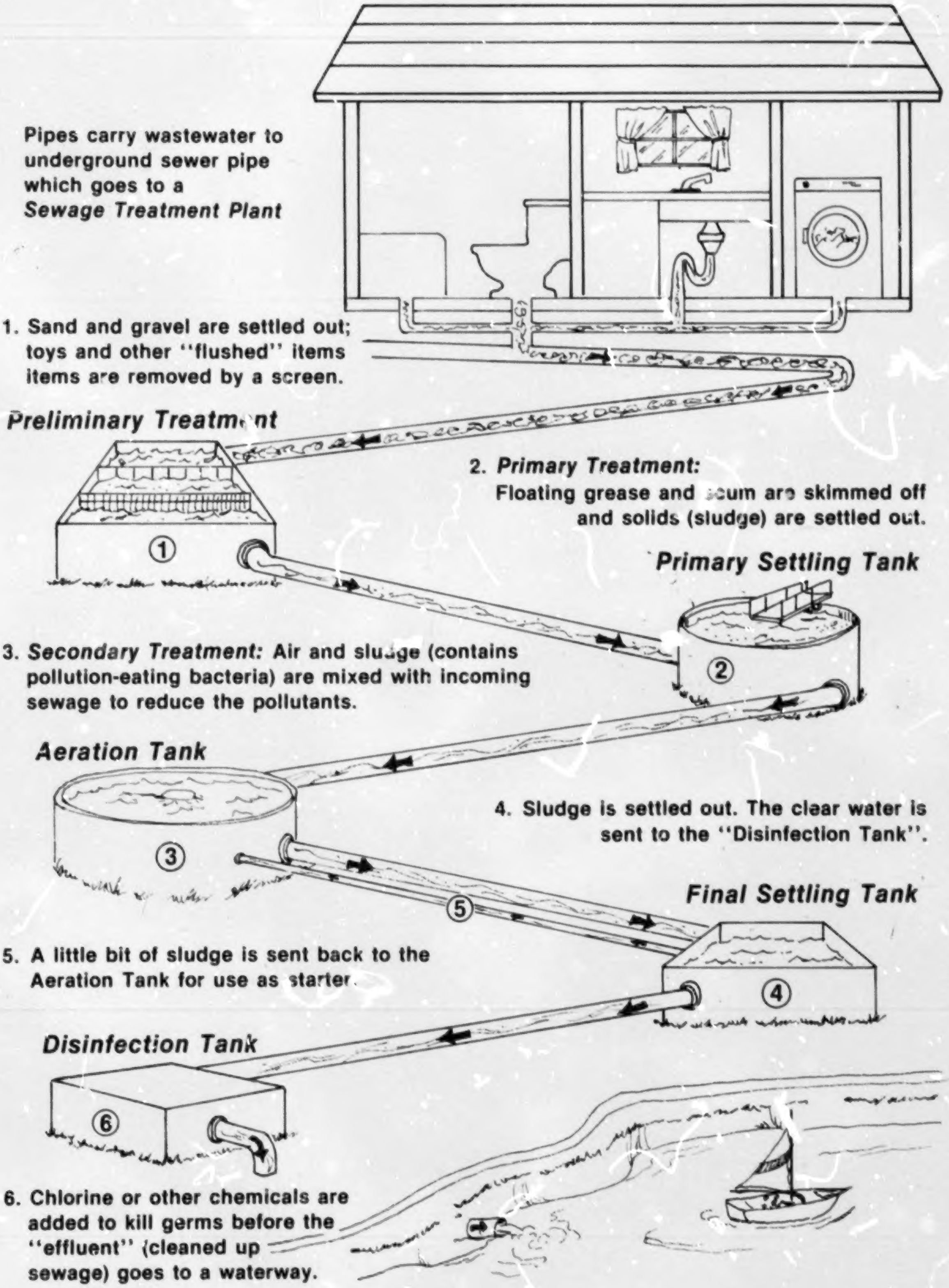
1. **Raw** or poorly treated sewage dumped by cities and towns.
2. Homes in the country with leaky septic tanks or septic tanks located too close to a water source.
3. Run-off from farm fields and cattle feedlots.

Raw sewage consists of toilet and city wastes which have not been filtered or treated. What goes through the sewers is *raw* sewage.

All big cities have some form of sewage treatment. But some small towns still have nothing at all. Often, they are forced to dump their raw wastes directly into a local river without any type of treatment. The result can be a foul-smelling, dangerous mess that kills fish and **aquatic** life and makes the water unsuitable for any form of recreation. (The Environmental Protection Agency or "EPA" is helping many of these towns set up some sort of sewage treatment.)

Aquatic organisms live in water.

Water pollution experts suggest all wastewater undergo *at least* primary and secondary treatment before it is released into a waterway (see Figure 15).



Pipes carry wastewater to underground sewer pipe which goes to a *Sewage Treatment Plant*

1. Sand and gravel are settled out; toys and other "flushed" items items are removed by a screen.

2. *Primary Treatment:* Floating grease and scum are skimmed off and solids (sludge) are settled out.

3. *Secondary Treatment:* Air and sludge (contains pollution-eating bacteria) are mixed with incoming sewage to reduce the pollutants.

4. Sludge is settled out. The clear water is sent to the "Disinfection Tank".

5. A little bit of sludge is sent back to the Aeration Tank for use as starter.

6. Chlorine or other chemicals are added to kill germs before the "effluent" (cleaned up sewage) goes to a waterway.

Preliminary Treatment
①
Primary Settling Tank
②
Aeration Tank
③
Final Settling Tank
④
⑤
Disinfection Tank
⑥

FIGURE 15 How a typical sewage treatment plant works

Scum is greasy material which floats on water.

Sludge is made up of heavy sewage wastes which settle out in water.

Primary treatment is a mechanical process that removes **scum** and **sludge** from the water. The scum and sludge are collected in huge settling tanks and later disposed of in a number of creative ways.

In the past, most sludge was burned, placed in landfills or dumped into the ocean. Now, much sludge receives additional treatment so it can be used as a soil conditioner and fertilizer. A few cities burn sludge along with garbage to produce energy for heating and lighting homes and factories.

Disinfect: to kill germs with chemicals. Alcohol is a common household disinfectant.

To complete the *primary* treatment phase, the effluent in the settling tank usually is **disinfected** with chlorine before it is discharged into the river. The chlorine kills harmful bacteria and destroys odors. But the amount of chlorine added must be just right. Too much chlorine will kill fish and organisms in the river. Too little chlorine doesn't kill enough bacteria.

Primary treatment removes about 30 percent of the crud. About one-fourth of all U.S. cities and towns -- mostly the smaller ones — *do not* treat their wastes beyond the primary stage!

Secondary Treatment

Secondary treatment is *biological* in nature. "Biological" comes from the Greek word "bios," which means "living things." The living things in the secondary treatment process are the **microorganisms** in the sewage.

Microorganisms and **microbes** are microscopic (too small to see without a microscope) animals and plants like protozoa, bacteria, yeasts and molds.

The idea is to create a favorable environment for the **microbes** so they'll eat the sewage and reproduce. (Microbes reproduce faster than rabbits. Some double their population in 20 minutes!) This is accomplished mainly by *aerating* (pumping air into) the sewage to provide plenty of oxygen for the bacteria. An aeration tank supplies oxygen to sewage in the same way as an air pump provides it for a fish tank. (Rivers are naturally aerated when water flows over rapids and falls.)

Chlorinated: Chlorine is added to kill bacteria.

After aeration, the sewage-microbe mixture is pumped to a settling tank where the microbes (called activated sludge) settle. The clear effluent is **chlorinated** or disinfected in some other way before it is released into a river, lake or (in rain-short areas) into an irrigation ditch so farmers can reuse the water right away.

When something is **incinerated,** it is burned up.

Small amounts of living microbes are called **starters.** Special *starters* are used to make cheese, yogurt and beer.

Because the microbe population increases (reproduces) a lot during aeration, much of the settled sludge is made into fertilizer or **incinerated.** The remaining sludge is sent back to the aeration tank to be used as a **starter** for treating more sewage.

Secondary treatment removes up to 90 percent of the biodegradable wastes in the water. Final chlorination kills up to 99 percent of all bacteria.

Secondary treatment does not make sewage "potable" (safe to drink). But it does clean the effluent well enough so that you can dump it into most lakes and rivers without hurting them.

Tertiary or Advanced Treatment

Tertiary or *advanced* treatment utilizes a variety of chemical procedures to remove metals and sophisticated compounds which primary and secondary treatment plants can't remove. Some of the most "advanced" sewage treatment plants are able to produce high quality drinking water from raw sewage!

One unique advanced treatment facility is located in San Diego, California. The San Diego water utilities department is unusual in that it must provide both drinking water *and* sewage treatment for the city. This difficult job is made even more difficult by the fact that San Diego receives so little annual rainfall. The city must import almost all of its drinking water . . . or purify its wastewater to use again.

The water department has tried many methods of recovering sewage water but none seems as promising as the use of **water hyacinths** in a controlled biological system. Here's how that system works: First, the sewage goes through a primary settling tank. Then the wastewater is drawn off and sent through tanks or ponds where water hyacinths grow. The plants absorb the organic wastes and remove most of the poisonous materials, including mercury, lead and cadmium. The water then flows through a second and third area containing more water hyacinths and some selected species of fish. Finally, the water is filtered and used for irrigation or is passed through a more sophisticated treatment process to make it **potable.** Neat, efficient . . . and beautiful!

Water hyacinths are a pesty water flower that grows in the stagnant waters of the deep South. These plants grow so thick they sometimes clog sewage systems.

Potable water is safe to drink.

Some Interesting Water Facts and Procedures

1. Small amounts of bacteria and harmful chemicals tend to accumulate in household plumbing which has not been used for some time. So when you return from a long trip, flush the water pipes in your home by running the cold water for a few minutes. This will wash out bacteria, sediments and chemicals which could be harmful.
2. If you don't like the taste of your city's chlorinated water:
    a. Install a screen device (available at hardware stores) on your faucet. The screen will break up the water stream and help chlorine (which is a gas) escape into the air.
    b. Pour your water into a large bowl and whip it with an electric mixer. The chlorine gas will be forced out of the whirling water.
3. If you have a "final filter" on your drinking water faucet, be sure to clean or replace it at regular intervals. Dirty filters may become overloaded with bacteria and sediment. They even may become an incubator for the growth of bacteria!
4. Not all bottled water sold in stores *is safe to drink*. Some brands have been found to contain intestinal bacteria and traces of chloroform. If you buy bottled water, get it from a reputable company with a reputation you trust!
5. If you're fishing or camping, *don't* drink water from lakes or rivers that:
    a. are stagnant (not moving). Stagnant areas provide ideal places for bacteria to breed.
    b. *look, smell or taste bad.*
    c. have a greenish color. Water with a green tinge contains algae and usually is loaded with microorganisms.
6. Here are some ways to purify water taken from lakes and streams:
    a. Boil it for at least five full minutes — up to 20 minutes at **high altitudes.** Boiling kills virtually all harmful bacteria and protozoa and is the safest method.

High altitude areas are many feet above sea level. (Denver, Colorado is 5,280 feet or one mile above sea level.) At high altitudes, boiling water is *cooler* than it is at sea level — so it takes more time to kill dangerous microbes.

b. Filter your water with one of the compact filtration devices sold in camping stores. Make sure the filter pore (hole) size is small enough to stop harmful microbes. (The sales person can help you select the proper filter.)

c. You can chlorinate water with either Halazone® tablets or common bleach. If you use Halazone, be sure to take an unopened bottle on each camping trip. Halazone must be protected from heat and exposure to air or it becomes ineffective. Be sure to follow label directions for use.

Liquid chlorine laundry bleach usually has 4 to 6 percent available chlorine. Read the label to find the percentage of chlorine and if yours is in the 4 to 6 percent range, use two drops per quart of clear water and four drops per quart of cold or cloudy water. Then, let it stand for 30 minutes. You should be able to smell chlorine. If not, repeat the dosage and let stand an additional 15 minutes before using. If water is very **turbid** or very cold, let it stand for several hours or even overnight to be sure it's safe to drink.

Turbid means cloudy.

d. Buy some iodine crystals at your local pharmacy. Weigh out six grams of iodine on a school laboratory balance. Put the crystals in a one-ounce amber bottle (or cover a clear bottle with tape). Fill the bottle with water.

Sterilize a quart canteen of water by pouring about half the iodine solution into the canteen. Let the canteen set at least 30 minutes before you drink the water. If your water is very turbid or very cold, it should sit several hours or even overnight before you use it.

Recharge the iodine bottle with fresh water after each use. It may be reused many times.

e. Globaline® is a commercial product that releases iodine. Available at many pharmacies and camping stores, it should be protected from heat and exposure to air. Campers should use a fresh, unopened bottle for each trip.

You're now familiar with some basic facts about water quality and are ready to test your own local water supply. Testing water is real experimentation. Even your teacher can't predict what you'll find!

You'll find the Hach Water Test Kits are easy to use and give very accurate results. Just follow the directions carefully and you'll get correct answers. If you live on a farm or in a rural area, now is the time to bring in a water sample for testing. Your teacher will tell you what tests may be run and what procedures to follow. If you don't like what you find in your water, contact your state pollution control agency. Don't assume that "because you're a kid" they won't listen to your complaints. They *will* listen, and if conditions warrent it, they *will* ac[illegible]

Don't be afraid to report violations of pollution control regulations to your state pollution control agency or health department. These agencies need all the help they can get to control pollution. How do you know if water's polluted? The answer is easy. If it looks or smells bad, it probably is bad! Don't hesitate to call your pollution control agency to check it out. The environment you save *will* be your own!